MATHEMATICAL ACHIEVEMENT AT AGE NINE YEARS OF CHILDREN BORN VERY PRETERM

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ABSTRACT

Children born very preterm (VPT) are known to be at high risk of under-achievement in mathematics. However the nature of these difficulties is poorly understood. In this study, a regionally representative cohort of 102 children born VPT and a comparison group of 108 children born full term (FT) during 1998-2000 were followed from birth to nine years. At age nine, children were tested using the Woodcock-Johnson III maths fluency subtest, and teacher reports of mathematical achievement and curriculum-based (numeracy project) achievement data were collected. The data was analysed using group comparisons and multiple regression. Parent and teacher ratings of executive function at age six were included as predictors. Findings indicated that children born VPT had elevated rates of mathematical difficulties across all measures including the standardised and curriculum-based measures, and teacher ratings. They also had higher rates of mathematical learning disability. With the exception of curriculum-based measures, these results remained significant even after controlling for socioeconomic status and severe neurodevelopmental impairment. Children born VPT showed particular difficulty using operational strategies, rather than with factual knowledge, and this effect was most marked for addition and multiplication. As well as difficulties in mathematics, children born VPT also showed more difficulty than children born FT in almost all areas of executive function. Difficulties with working memory at age six were significantly associated with poor performance in aspects of curriculum-based measures at age nine.

CHAPTER 1

INTRODUCTION

The last 25 years have seen a steady increase in the survival of infants born preterm (less than 37 weeks of completed gestation), and/or low birth weight (less than 2500g). Since the mid-1980s figures have risen by 36% for children born preterm, and 24% for children with low birth weight. In 2006 in the US, 8.3% of all live births were low birth weight, the highest rate reported since 1968 (Martin, Hamilton, Sutton, & Ventura, 2009). In 2006, 12.8% of all live births were preterm, and 2% were very preterm (less than 32 weeks). These figures were higher than in New Zealand, where in 2005 7.2% of all live births were preterm and 1.3% were very preterm (New Zealand Health Information Service, 2008). Based on these statistics, an average sized classroom is likely to contain up to four children who were born preterm, and for every 100 children enrolled in a school, there may be two children born very preterm (Hornby & Woodward, 2009). Given the increasing prevalence of children born very preterm, it is important to understand the nature and extent of difficulties faced by this population during the school years, in order to best learn how to identify potential problems early, and to provide intervention and remediation as appropriate.

General Developmental Outcomes

Traditionally the follow-up research with children born preterm has tended to focus on these children's later risk of severe neurodevelopmental impairment. Studies have shown that around 5-15% of children born very preterm have severe neurosensory disability, including cerebral palsy, blindness, and deafness (Woodward, Anderson, Austin, Howard & Inder, 2006).

In addition to these neurodevelopmental difficulties, between 25-50% of children born very preterm (VPT) have less severe, but nonetheless clinically relevant deficits, such as lower IQ scores and specific cognitive deficits. Studies have revealed that children born VPT score lower on standardised measures of IQ than their classmates born full term (FT). For example, Johnson (2007) investigated developmental outcomes of children born extremely preterm and found that at six years of age these children were more likely to have lower IQ scores than children born FT, as measured on K-ABC. Results from the Victorian Infant Collaborative Study cohort of children born extremely preterm similarly showed these children to be more likely than their FT peers to have lower IQ scores at eight years of age, as measured on the WISC-III (Anderson & Doyle, 2003). Furthermore, a gradient effect is evident, with children born at earlier gestational ages scoring lower than those born later. IQ has been shown to decrease by approximately 1.7 points per week of gestation (Johnson, 2007).

Cognitive functioning among children born VPT is a less well-studied area. Existing research has shown that these children are at greater risk that their FT peers of having specific cognitive deficits, such as language delay, visuomotor difficulties, inattention, verbal memory difficulties, learning difficulties, and executive dysfunction (Anderson & Doyle, 2008). For example, Whitfield, Grunau and Holsti (1997) compared the functional abilities of 90 children born extremely low birth weight with 50 children born FT and found that children born extremely low birth weight had significantly lower scores than children born FT on measures of visual memory and visuo-motor performance. Similarly, Breslau, Johnson and Lucia (2001), in their study of 411 children born low birth weight and 306 children born normal birth weight, found that phonologic awareness and visual-motor-integration, assessed at age 6, were predictors of reading and mathematical ability at age 11, independent of IQ. They suggest that children born very low birth weight are more at risk for weaknesses in visual-perceptual than verbal skills, which will likely result in poor academic achievement.

Academic Outcomes: General School Progress

Educational progress is an important, but less well researched area in the study of children born preterm. There is growing evidence to show that children born VPT are at risk of poorer academic outcomes than children born FT, such as performing below average or below expected grade level, requiring extra support, and of being diagnosed with a learning disorder (Anderson & Doyle, 2003; Anderson & Doyle, 2008; Breslau, Johnson & Lucia, 2001; Johnson et al., 2009; Pritchard et al., 2009). For example, Pinto-Martin et al., (2004) investigated the prevalence of special education services amongst children born VPT and concluded that almost one third of their sample of 868 children born low birth weight were in a special education placement. Thirteen percent of the study children had either repeated a grade, or were recommended to do so.

For children born VPT in the mainstream education system, difficulties occur in several basic curriculum areas, including reading, spelling, writing and mathematics (Anderson & Doyle, 2003, Grunau et al., 2002, Litt et al., 2005, Schneider et al., 2004). For example, Schneider, Wolke, Schlagmuller and Meyer (2004) compared the reading, spelling and mathematical abilities of 264 eight year olds who were born VPT to 264 children born FT. Results showed that children born FT outperformed children born VPT on all measures of reading, spelling, and mathematics, with group differences ranging from one half to almost one standard deviation. Likewise, a study by Horwood, Mogridge and Darlow (1998) comparing the school achievement of a national cohort of 298 children born VPT with a sample of over 1000 children born in Christchurch showed that children born VPT were twice as likely as children in the general population to have below average performance not only in reading, written expression, mathematics, spelling, but also in physical education.

These academic difficulties are present upon school entry, persist into adolescence, and complicate the transition to adult life. In their study of children born extremely low birth weight (less than 800g), Grunau, Whitfield and Fay (2004) found that at age 17, compared with FT peers, children born extremely low birth weight were more likely to obtain lower scores on measures of cognitive ability, and mathematics and reading ability. Participants were also asked to rate themselves on scholastic, athletic, job and romantic competence. Children born extremely low birth weight rated themselves as less competent than FT peers on all these scales. In order to help each child reach his or her potential, difficulties need to be identified as early as possible and appropriate support given.

Cost of Very Preterm Birth to Health and Education

While children born VPT comprise only a small proportion of total births, they contribute the biggest workload of New Zealand's neonatal units (New Zealand Health Information Service, 2008) and result in lifelong costs not only for education, but also for health, and social services. A review by Petrou, Sach and Davidson (2001) analysed the results of 20 studies published between 1980 and 1999, which included over 12500 children with birth weights less than 2500g. Investigating the societal costs of being born VPT or very low birth weight Petrou et al. found that preterm birth or low birth weight can often result in substantial costs to health services, social services, and education. For example, children born VPT were more likely to be rehospitalised than children born FT and twice as likely to visit the GP. Due to the increased likelihood of children born VPT to have neurosensory impairment or cognitive disabilities the cost to social services are through day care programmes, case management and counselling, respite care and residential care. However, the greatest long-term costs were shown to be in the educational system. Educational costs included high rates of learning problems and school failure, increased need for additional educational assistance, increased enrolment in special education services, and higher rates of grade repetition and school drop-out. For example, one of the studies Petrou, Sachs and Davidson reviewed reported that children born VPT were 50% more likely to be enrolled in a special education service, estimated to cost the country £323 million per year due to preterm birth. In addition to these findings, they also argued that the earning potential of individuals born VPT would be likely to be lower, resulting in a greater long-term reliance on social welfare. In another study, Petrou et al. (2006) estimated the mean cost per year to education, of 241 children born extremely preterm (between 20 and 25 weeks gestation) at six years of age to be £7620, compared to an average of £3470 per person per year for children born FT. Given the high cost to the education system, it is important to understand the nature and extent of difficulties encountered by children born preterm, in order to be able to identify difficulties earlier and to design remediation, to better help these children and to reduce the costs.

Review of Previous Literature

In order to identify previous research examining the mathematical achievement of children born VPT or very low birth weight, searches of PubMed, PsycInfo and ERIC were conducted. Keywords used were premature, preterm, low birth weight, mathematics, school, and achievement. Criteria for inclusion were very preterm or very low birth weight, born after 1985, and inclusion of a measure of mathematic achievement. Sixteen studies were identified and are presented in Table 1.

Table 1.
Overview of Studies Involving Mathematical Assessments with Children Born Very Preterm

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
Anderson & Doyle (2003) Neurobehavioural outcomes of school-age children born ELBW or VPT in the 1990s	To examine cognitive, educational, behavioural outcomes of ELBW/EPT compared to full term peers	ELBW: 298 children <1000g or <28weeks NBW: 262 children >2499g ELBW =92.3% NBW = 85.1% sample retention Analyses run with and without children with neurosensory impairment Regional cohort Australia born 1991-2	8	Wide Range Achievement Test – 3 (WRAT-3) Arithmetic Comprehensive Scale of Student's Abilities (CSSA) Mathematic (teacher report) Impairments definition: Major impairment if scale scores less than 70 Mild impairment determined by scale scores 70 to 84	WRAT-3 Mean Difference a) -8.3 excluding children with Neurosensory Impairment b) -8.5 after adjustment for socio-demographic variables CSSA Mathematics a) -9.4 b) -7.8 Proportion of children with minor and major impairments in Arithmetic: None 67% vs. 88% Mild 26% vs. 11% Major 7% vs. 1%	WRAT3 maths: ELBW children scored below average range, and had lower scores than ctrl CSSA Teacher report: ELBW children lagging behind term peers in maths	+ Analysed both with and without neurosensory impaired children + Adjusted for sociodemographic variables + Controlled for IQ +large sample size
Bowen, Gibson, & Hand (2002) Educational outcome at 8 years for children who were born EPT: a controlled study	To assess the educational outcome and utilisation of special education resources at age 8 years in children who were born EPT, compared with full term peers	48 children without major disability (IQ>85, no NSI) <28weeks or <1000g 48 matched control child	8	Test of Early Mathematics Achievement 2 Ed (TEMA-2) Teacher report on academic progress	TEMA-2 Maths Quotient EPT mean/SD 90.8 +-11.0 FT mean/SD 104.5 +- 12.2 Maths TEMA-2: Far below average (<10th percentile)	90% of EPT infants were free from severe disability, 43% required special education support and only 30% were functioning at grade level in both reading and maths, without special education support. Compared to peers, EPT	+ High follow up rate (94% preterm) + well matched control group +Comprehensive assessment of academic performance (i.e. standardised and teacher

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
		94% sample retention 1 hospital (tertiary) cohort AUST Born 1985-1990			10%EPT vs. –FT (no data) Below average (10–24th percentile) 36%EPT vs. 10% FT Average or above 54%EPT vs. 90% FT Teacher report: More likely to be reported by teachers as falling below grade level in maths (far below 10% (-), below 38% (10%), at or above 52% (90%)	children free of disability obtained lower scores on standardized tests of academic achievement, were more likely to be reported by their teachers as achieving below their expected grade level in reading, mathematics or spelling and were six times more likely to be receiving special education support services at school.	report)
Chaudhari, Otiv, Chitale, Pandit, & Hoge (2004) Pune low birth weight study – cognitive abilities and educational performance at 12 years	To assess the intelligence, visuo-motor perception, motor competence and school performance of children with birth weight less than 2000g, at the age of 12 years	180 children By weight: VLBW/<1500g n=78 LBW/1500-2000g n = 102 By gestation: FT n = 33! <32wks n= 27 33-34 n= 70 35-36 n= 50 90 control children >=2500g		WRAT maths	WRAT: Ctrl 87.8 (15.8) By weight: <1500g 80.4 (15.1) 1501-2000g 84.4 (17.9) By gestation: Preterm SGA 81.6 FT SGA 82.7 Preterm AGA 83.7	The mathematical skills of LBW children were poor when compared with controls, the VLBW and preterm SGA group fared the worst. There were no between group differences for WRAT reading measure	+ Included SGA children - Some FT children in the VLBW group

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
		Excluded children with CP or IQ < 70) 1 hospital India Born 1987-89					
Foulder-Hughes & Cooke (2003) Motor, cognitive, and behavioural disorders in children born very preterm	To compare motor, cognitive and behavioural disorders in children born very preterm with children born FT	280 VPT 210 control 91% eligible families recruited Only included children in mainstream schools Regional cohort UK Born 1991-92	7-8	WISC-iii arithmetic	WISC Arithmetic VPT mean (sd): 10.3 (3.2) Control mean (sd): 11.4 (2.8)	Children born very preterm scored significantly lower than the control group on the arithmetic test	- Retrospective study meant that it was not possible to recruit all eligible families - Not all children completed every test + Children matched for age and gender
Hagen, Palta, Albanese, & Sadek-Badawi (2006) School Achievement in a regional cohort of children born very low birth weight	To compare school achievement of VLBW children and NBW children, with respect to changes in neonatal care	313 VLBW children Follow-up cohort: 23.5% data for WKCE 40.5% data for TRF 6 hospitals USA Born 1988-1991	10	Maths subtest Wisconsin Knowledge and Concept Exam (WKCE) (control was distribution of all children in that area) Achenbach Teacher Report Form (maths) (control was one child in the class with birthday closest to VLBW	WKCE Math VLBW (n = 147) min. 2.7% vs. 2% basic 30% vs. 21% proficient 56% vs. 47% advanced 12% vs. 30% Mean TRF score for maths (scale of 1-5) was 2.7 for VLBW and 3.3 for controls (n=253)	WKCE maths: birth weight, social function measured at age five, SES, and the family's relative SES were each independent predictors of higher achievement. Suggest increased post-natal steroid use as a cause of poorer maths performance Gap is biggest in maths than other subjects	+ Good timing of study around when neonatal care changed, so were able to study effects - Large attrition rate to 10 years, participation bias + Large sample size - More VLBW than control children did not sit WKCE due to it not being 'appropriate' for the child, so not a true

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
				child)			picture of VLBW
Horwood, Mogridge, & Darlow (1998) Cognitive, educational, and behavioural outcomes at 7 to 8 years in a national VLBW cohort	To examine cognitive, behavioural, and educational outcomes in middle childhood among a birth cohort of VLBW children	77 ELBW (<1000g) 221 VLBW (1000-1500g) Adjusted for children with NSI 1092 children in general population (born 1977) 91.4% sample retention National cohort NZ Born in 1986	7-8	Teacher rating of school performance (scale 1-5, score then classified as below average or not)	Teacher rating of below average in maths: <1000g 37.5% 1000-1499g 37% FT peers 15.9%	Children with VLBW had higher rates of problems than control children	+ Large sample, pop based regional cohort + Controlled for gender, maternal education, parity, single parenthood, duration of breastfeeding, maternal smoking during pregnancy, age at assessment - Children in VLBW group were younger than comparison group children - Used gross measures of impairment that would show large numbers of children with deficits in any child sample - Doesn't use standardised measure - Ctrl cohort were born 9 years earlier than VLBW sample, potential cohort effects
Huddy, Johnson, & Hope (2001) Educational and behavioural problems in babies of 32-35 weeks gestation	To identify incidence of school and behavioural problems at age 7 years in children born between 32 and 35 weeks gestation, and investigate perinatal risk factors	117 children VPT 66% sample retention Regional cohort UK Born 1990		Teacher rating, 5 point scale on maths performance	Score >3 in mathematics (indicates poor outcomes) 32-35wks (29%) 32wks (42%) 33wks (23%) 34wks (29%) 35wks (31%)	Up to 1/3 of children born 32-35 weeks GA will have problems at school.	-No control group -34% attrition (but bias tends to underestimate the problem)

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
Johnson, Hennessy, Smith, Trikic, Wolke, & Marlow (2009) The EPICure Study: academic attainment and special education needs in EPT children at 11 years	To assess academic attainment and special education needs in EP children in middle childhood	219 EP children (<=25 weeks) 153 matched term children Birth cohort UK & Ireland Born 1995	11	WIAT-II (maths: numerical operations, mathematical reasoning) Intuitive maths estimation test (e.g. estimating number of dots, lengths of lines, scores range 0-11) Maths Impairment criteria: None: > -1SD Mild: -1SD to -2SD Moderate: -2SD to -3SD Severe: < -3SD Using mean and SD of classmates WIAT-II test	WIAT-II Maths EP 71.2 (20.9) Ctrl 98.5 (15.0) Mean difference - 27 Numerical Ops EP 75.6 (18.4) Ctrl 98.0 (15.5) Mean difference - 22 Math Reasoning EP 78.2 (18.1) Ctrl 99.7 (12.0) Mean difference - 21 Maths Estimation test: EP 4.4(2.0) Ctrl 6.6 (1.9) Mean difference - 2.2 Maths Impairment: None: 30.2% (86.3%) Mild: 26.0% (12.4%) Moderate: 19.5% (1.3%) Severe: 24.2% (0)	EP had lower scores than ctrl in maths, on WIAT (mean deficit of 25 points) but not reading, supporting specific deficit theory in maths difficulties EP children had increasingly lower maths scores at lower mental processing composite (MPC) scores than classmates	+ Only studied EP + Compares with peers, not std norms - Haven't recorded extra support SEN children may receive at home - Attrition of poorer functioning children +Adjusted for SES, MPC +Large sample size
McGrath & Sullivan, (2002) Birth weight, neonatal morbidities,	To examine the relationship between birth weight and neonatal morbidities, and later school age	51 LBW (1500-2499g) 52 VLBW (1000-1499g) 48 ELBW	8	WRAT 3 arithmetic	WRAT Mean (SD) FT 100.2 (14.8) LBW 91.3 (13.9)	Children born ELBW/VLBW scored lower than NBW children in maths Gradient relationship found	+ Also break analysis down by medical conditions (BPD, CLD, IVH, sepsis)

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
and school age outcomes in FT and preterm infants	outcomes	(<1000g) 37 FT 97% sample retention 1 hospital USA Born 1985-89			VLBW 90.3 (19.0) ELBW 88.7 (19.8)		
Pinto-Martin, Whitaker, Feldman, Cnaan, Zhau, Bloch, McCulloch, & Paneth (2004) Special education services and school performance in a regional cohort of LBW infants at age 9	To examine the prevalence of SE placement and it's relationship to maths achievement scores in LBW children	645 children weighing 500-2000g 75.9% sample retention Birth cohort USA Born 1984-87	9	WJ-R maths subtests	W-J Maths mean (SD) <=1000g (n=60) 97.9 (21.2) 1001-1500g (n=177) 102.9 (17.6) 1501-2000g (n=267) 108.8 (17.4)	Among children in special education as well as those not in special education, a birth weight gradient was found for maths Children in special education scored lower than those not in special education placements	+ Very large prospective longitudinal study - 24% lost to follow up
Pritchard, Clark, Liberty, Champion, Wilson, & Woodward (2009) Early school-based learning difficulties in children born very preterm	To describe educational progress of VPT and full term children at 6 years and examine the extent to which VPT children are at elevated risk of SLD in reading, receptive language and/or maths	102 VPT children (Mean = 28weeks) 108 full term children (Mean = 40weeks) Analyses run with and without children with neurosensory impairment 97% sample retention	6	WPPSI-R (arithmetic) WJ-III (Maths fluency) Teacher report (5 point scale, maths achievement compared to class peers) School maths tests (NumPA) Low achievement	WJ-III Math Fluency Mean (SD) FT (n=108) 101.20 (12.99) VPT (n=102) 86.18 (24.30) Teachers rated 43.6% VPT and 13.5% term children as below average maths VPT children had lower scores on maths fluency, all	Educational delays were evident in VPT children at age 6 across multiple measures of math, in both laboratory and school-based settings With the exception of WJ-III scores for language, few sex differences were evident amongst children born VPT. Poor school function was not restricted to VPT children with neurodevelopmental impairments VPT birth is associated with	+ Range of measures, specific about maths categories + Demographically representative sample + High sample recruitment + Controlled for severe neurodevelopmental impairment, SES

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
		Regional cohort NZ Born 1998-2000		definition of LD used (i.e. an achievement score of 1 or more SD below the FT comparison group)	domains of NumPA VPT children had relative risks of math impairment that were twice that of FT children (46.5% vs. 22.1%)	higher rates of LD in math at age 6	
Saigal, den Ouden, Wolke, Hoult, Paneth, Streiner, Whitaker, & Pinto-Martin (2003) School-age outcomes in children who were ELBW from four international population-based cohorts	To determine whether learning and school problems in ELBW and reference children differ between cohorts in different countries	4 cohorts of ELBW children (500-1000g) from US, Canada, Germany, Holland (n=532) Sample retention range: 60-90% Various years, some post 85.	8-11	Maths Achievement a) WJ (new Jersey) b) WRAT (Ontario) c) Maths Ability Test (Bavaria) d) Maths, Tempo Test (Holland)	Arithmetic Achievement: Abnormal (<70) New Jersey 15% Ontario 25% Bavaria 47% Holland 30% Borderline (70–84) New Jersey 9% Ontario 15% Bavaria 22% Holland 13% Normal (>=85) New Jersey 76% Ontario 60% Bavaria 31% Holland 57% ELBW children in normal range for maths achievement was 31-76% across 4 countries	Up to half of VLBW children will experience difficulty at school	- No control group -Comparing different countries on different measures, with different norm referencing -Only 60% followed up in New Jersey sample -Several methodological differences between countries + Population-based study
Schneider, Wolke, Schlagmuller, & Meyer (2004) Pathways to school	To investigate individual differences in academic success in VPT children, in particular, how	264 VPT children (<1000g n=57 1000-1500g n=135 1500-2000g +	6, 8 & 13	Maths Test (A German adaptation of the test package by Stigler, Lee, and	Mathematics test (8.5yrs) VLBW 12.45 (5.19), Control 16.30 (3.39)	VPT children performed lower than FT peers on maths test Differences in birth weight predict school achievement,	+ Large sample size + Children matched for gender, SES, marital status of parent and maternal age

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
achievement in VPT and full term children	cognitive skills at age 6 and 8 impact on success at age 13	<32wks n=72) 264 matched children born full term 75.6% sample retention Whole population Germany Born 1985-86		Stevenson (1990)). Subtests are: Estimation of sizes. Reasoning, and Visualization	Mathematics test By birth weight: ELBW 9.38 (5.38), VLBW 12.75 (4.93), LBW 14.59 (4.24), Control 16.30 (3.39)	poorest outcomes for ELBW and VLBW, whereas LBW seemed closer to controls	
Short, Klein, Lewis, Fulton, Eisengart, Kercsmar, Baley, & Singer (2003) Cognitive and academic consequences of bronchopulmonary dysplasia and VLBW: 8 year outcomes	To examine the effect of BPD and VLBW on cognitive and academic achievement at age 8	VLBW children with BPD (n=98), without BPD (n=75), 99 FT infants 90% VPT sample retention, 80% FT Analyses run with and without children with low IQ Regional cohort US Born 1989-91	8	WJ-R (Calculation and Applied problems)	Calculations mean (SD) BPD 84.8 (23), VLBW 94.0 (18), Term 106.4 (19) Excluding low IQ: BPD (n=49) 90.5 (21), VLBW (n=55) 94.6 (16), Term (n=99) 106.4 (19) Applied Problems mean (SD) BPD 91.4 (25), VLBW 103.8 (17), Term 112.2 (15) Excluding low IQ: BPD (n=49) 96.9 (23), VLBW (n=55) 104.7 (16), Term (n=99) 112.2 (15)	VLBW children with BPD had more maths difficulties than VLBW and control children BPD children performed more poorly than VLBW and term comparison children on tests of math abilities and were nearly 1 standard deviation below the mean on the calculation subtest.	+ Included a comparison of VPT children with BPD + Children matched for gender, race, SES, maternal education, marital status

Author	Aims	Design/Sample	Age	Measures	Results	Conclusions	Strengths/Limits
Wocadlo & Rieger (2007) Phonology, rapid-naming and academic achievement in VPT children at 8 years of age	To examine the impact and additive effect of phonology and rapid-naming defects on reading, spelling and maths in VPT children	63 VPT children (<30weeks) Excluded children with NDI or IQ < 85 72.8% sample retention 1 hospital AUST Born 1994-95	8	Test of Early Mathematical Achievement 2nd Ed (TEMA-2) Low academic achievement in mathematics was defined as a score below the 25th percentile on the appropriate standardised test of achievement.	TEMA-2 mean score 97 (range 73-131) 29 children had additional support, of these 20 had delays in maths, of the 20 children who had maths difficulties, 14 also had reading and/or spelling difficulties	Preterm children show higher than expected rates of academic delay	- Small sample size - No control + Excluded children with neurosensory disability or IQ < or =85 - Focus is on reading and multiple delays, so not much maths achievement detail
Wocadlo & Rieger (2008) Motor impairment and low achievement in very preterm children at eight years of age	To examine the concurrence of motor impairment and academic underachievement in a group of very preterm children at 8 years of age	323 VPT (<30 weeks) 2 groups based on developmental coordination disorder: 101 DCD 222 No DCD Excluded children with NDI or IQ < 85 Data available for 46.9% of children surviving to 8 years Single hospital Australia Born 1987-97	8	Children born 1987-91 = WIAT 1992-94 = TEMA (Both are norm referenced and give percentiles) Low achievement in maths defined as a score < 25th percentile	WIAT/TEMA median (min-max) DCD 92 (73-131) No DCD 96 (75-139) Low achievement in mathematics DCD 80.9% No DCD 26.1%	Median scores for both groups of children born VPT were below average, and children with DCD scored significantly lower than those without DCD. More children in the DCD group than in the No DCD group had low achievement in mathematics	+ Excluded children with neurosensory impairment or low intelligence (IQ<=75) - No control group - Large attrition rate + How that academic delays increase with severity of DCD

Mathematic Difficulties in Children Born Very Preterm

Although children born very preterm show a wide range of academic difficulties, problems in mathematics appear particularly common (Anderson & Doyle, 2008; Johnson et al., 2009; Pritchard et al., 2008; Taylor, Espy & Anderson, 2009). Indeed, research tends to suggest that children born VPT may have a greater degree of difficulty in mathematics than in other subjects (Anderson & Doyle, 2003; Johnson et al., 2009). For example, Johnson et al.'s (2009) study examined the effects of extremely low birth weight on academic achievement. They assessed the reading and mathematical abilities of 219 children born less than 26 weeks gestation and 153 matched term born comparison children at age 11. Results showed an average 25-point group difference for mathematics, as measured on the WIAT-II (standardised mean of 100, standard deviation of 15 points), but no significant between-group difference for reading. Likewise, the study by Anderson and Doyle (2003), of a group of 298 children born extremely preterm and 262 children of normal birth weight, revealed a mean difference of more than 8 points for mathematics achievement, but no significant differences for reading or spelling achievement.

It could be argued that these findings could reflect the poor mathematical performance of a subset of children with severe neurodevelopment impairment (NDI). This issue is dealt with in the studies reviewed either by excluding from analysis those children with low IQ or severe NDI (four studies), by running analyses both with and without children with low IQ or severe NDI (three studies), by statistically adjusting for NDI (three studies), or by only administering the tests to children in mainstream schools and/or to children for whom the test was cognitively appropriate (two studies). Three studies did not use a FT control group, so did not control for IQ or NDI and one further study with a control group also did not control for IQ/NDI. The differences in mathematic achievement may have been attenuated somewhat, but nevertheless remained significant even after controlling for IQ/NDI. Children born VPT consistently scored significantly below average, and had significantly lower mathematics scores than those children born FT.

In all the studies reviewed here, the measures used to assess mathematical achievement of children born VPT are typically limited to standardised tests and teacher report regarding academic performance. Some researchers have then used these measures to classify children as having a mathematical impairment or learning disability. Results from the articles in this review are discussed below.

Lower scores on standardized tests of achievement. The most commonly used standardised measures of mathematics achievement in studies were the Wide Range Achievement Test (WRAT) and the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R). Regardless of the measure used, results across articles using standardised tests consistently show that children born VPT obtained lower scores than children born FT, with differences typically ranging between half to one and a half standard deviations. For example, Anderson and Doyle (2003) compared the mathematical achievement of 256 eight-year-old children with extremely low birth weight with 217 children with normal birth weight, using the Wide Range Achievement Test – 3. They reported that children with extremely low birth weight scored significantly below children with normal birth weight, with a difference of more than half a standard deviation. Similarly, Short et al. (2003) measured the mathematical achievement of 75 eight-year-old children with very low birth weight and 99 children born FT, using the WJ-R calculation and applied problems subtests and found that children born very low birth weight had lower scores than children born FT, with group differences ranging from one half to two-thirds of a standard deviation.

The use of standardised measures of mathematical achievement such as WJ and WRAT results only in broad scores of general mathematical achievement. At the very most, these can be separated into only three more specific areas. For example, the WJ has three subtests (calculation, applied problems and maths fluency); however most studies used only the first two subtests. Both the WIAT and WOND include subtests for numerical operations and mathematical reasoning. Notwithstanding, most studies sum these subtest scores to create a single composite score for mathematics, making it impossible to compare performance over specific component areas of mathematics.

Those studies that do report results of specific subtests (Johnson et al., 2009; Short et al., 2003) indicate that children born VPT perform more poorly than FT peers on all mathematics subtests, and that differences are greater for tests of calculation of basic facts than for tests of problem solving/reasoning. For example, Short et al. (2003) tested 75 children with very low birth weight and 99 children born FT, using the calculations and applied problems subtests of the WJ-R, a standardised measure with mean of 100 and standard deviation of 15. The difference between these groups was 12 points for the calculation test and 7.5 points for the applied problems test, in favour of children born FT, even after excluding children with low IQ scores. Similar results were found by Johnson et al. (2009) who assessed 219 children born extremely preterm and 153 children born FT using the numerical operations and maths reasoning subtests of the WIAT-II and found a 22 point difference in favour of the FT group for the numerical operations test, and a 21 point difference for the maths reasoning test. The difference in performance for these subtests is larger than that found by Short et al., possibly because Johnson et al.'s study focuses only on children born extremely preterm, who are likely to have more difficulties than children born later.

Poorer performance on mathematic component skills. These assessments are too broad, however, to be able to ascertain where specific strengths and weaknesses may lie, and to speculate as to the underlying mechanisms causing the deficits. It is possible that some components of mathematics may be more problematic for children born VPT than others. Studies have shown, for example, that difficulties with counting ability, understanding number magnitude, and an ability to represent quantity may be correlated with lack of success in mathematics (Geary, Hoard, Byrd-Cracen, Nugent, & Numtee, 2007; Gesten et al., 2005; Isaacs, Edmonds, Lucas & Gadian, 2001).

In a commonly used measure in the New Zealand school setting – the numeracy project assessment - a distinction is made between strategy and knowledge. Strategy refers to the mental processes children use to solve problems (in addition and subtraction, multiplication and division, and with proportions and ratios), whereas knowledge pertains to the key items of knowledge that children need to be able to recall in order to problem solve. Key items of knowledge can be further broken down into number identification, number sequence, grouping and place value, and basic facts. To be successful in mathematics, children need to be proficient in both domains. Strong knowledge enables children to develop more advanced strategies, and using strategies creates new knowledge.

Using the numeracy project assessment and the same longitudinal sample as the current study, Pritchard et al. (2009) obtained data from school records for 102 six-year-old children born VPT and 108 children born FT. This measure included scores for several specific mathematical competencies, including operational strategies, forwards number sequence, backwards number sequence, numeral identification, place value, and basic facts. Results showed that children born VPT were more likely to perform below the national norm in forward number sequence (27% of FT vs. 51% of VPT), backwards number sequence (16% vs. 33%), and numeral identification (18% vs. 38%), but not operational strategies (16% vs. 26%), or place value (20% vs. 26%). This suggests that there are areas of specific difficulty within the broader mathematics curriculum, and that not all mathematical concepts are problematic for children born VPT. Further investigation is therefore needed to better understand the specific areas of strength and weakness in mathematics among children born VPT.

Poorer teacher ratings. Several studies included a teacher report measure in which teachers indicated how well the child was doing in mathematics (Anderson & Doyle, 2003; Bowen, Gibson & Hand, 2002; Hagen et al., 2006; Horwood, Mogridge & Darlow, 1998;

Huddy, Johnson & Hope, 2001; Pritchard et al., 2009). This was commonly converted into binary data as to whether the child was performing below average or not. Results from these studies indicate that children born VPT are between two and five times more likely to have below average mathematics achievement than their FT peers, as rated by teachers. For example, Bowen, Gibson and Hand (2002) examined teacher reports on mathematic progress in a group of 82 children born extremely preterm and a group of 48 children born FT, matched for age and gender. Results indicated that as many as 48% of children born extremely preterm were achieving below average, compared to 10% of their FT peers. The high proportion of children with below average performance in this study may be due to the fact that only children born extremely premature were included, and that this study does not have a large sample size. Despite these methodological limitations, their results are supported by other studies. Other research with children born preterm, but at a later gestational age still shows a large number of these children performing at below average levels in mathematics. For example, Huddy, Johnson and Hope (2001) investigated the proportion of children born between 32 and 35 completed weeks of gestation who had below average performance on teachers rating of mathematical achievement (n=117). They reported that on average, 29% of these children were rated by teachers to have difficulties in mathematics. Their study had an attrition rate of 34%, however if this were to have any effect on the outcome, it would most likely underestimate the problem, as there was an over-representation of the lowest gestation children in the non-responding group.

Mathematical learning disability. In addition to standardised tests and teacher ratings, several studies have examined the extent to which children born VPT may have a mathematics learning disability (MLD). Learning disabilities can be identified by one of two methods. The *low achievement* definition identifies children who score below a given percentile (cutoffs used range from 6th to 35th percentile), but whose general cognitive performance (IQ) is within the normal range (usually > 80). A *discrepancy definition* identifies children whose mathematics test score is lower than expected given the child's IQ. Of the articles reviewed, all used the low-achievement definition.

Results from the review articles range from 33-70% of children born VPT having some level of MLD, compared with 12-22% of control children having some MLD. Furthermore, 7-24% of children born VPT have major/severe impairments in maths, compared to 1% or less of children born FT. For example, Johnson et al. (2009) used the WIAT-II mathematics test to determine the proportion of 11-year-old children who had a MLD, comparing those born extremely preterm to those born FT. The severity of MLD was calculated according to number of standard deviations below the mean of the FT group and were classified as *severe* (less than or equal to 3 standard deviations below), *moderate* (two to three standard deviations below), *mild* (one to two standard deviations below) or *none* (score within one standard deviation of FT group). They found that 70% of children born extremely preterm had some level of MLD, compared to 14% of children born FT. Twenty-four percent of children born extremely preterm had severe mathematics difficulties, compared to no children born FT. Twenty percent of children born extremely preterm had moderate difficulties and 26% had mild difficulties, compared to 1% and 12% of children born FT, respectively. One explanation for the high estimates for the prevalence of MLD may be that the authors did not exclude children with low IQ, although they do note that there was an over-representation of children with severe cognitive difficulties in the group of children lost to attrition.

Pritchard et al (2009) found less extreme results in a study of the current VPT sample at six years of age, including children with IQ greater than 83. They classified a child as having a MLD if he/she scored one or more standard deviation below the FT comparison group. They found that 46.5% of children born VPT had a MLD, compared to only 22.1% of children born FT, indicating that children born VPT are twice as likely as children born FT to have a MLD. One possible reason for the difference in these estimates of MLD prevalence is that the participants in Johnson et al.'s study were five years older, and may therefore be exhibiting the

Matthew effect (Stanovich, 1986), in which children with learning disabilities fall further and further behind the more they progress through the school years. Furthermore, Johnson et al. focused on children born extremely preterm, who have been shown to have more difficulties than those born VPT.

Gradient effect of low birth weight. In addition to showing that children born VPT are at increased risk of mathematical difficulties, research has also found that the risk of these difficulties increases with level of prematurity, with those children born at earlier gestation more likely to have difficulties than those born later. For example, Pinto-Martin et al. (2004) found that children weighing <1000g at birth scored six points lower than children weighing 1001-1500g on the Woodcock-Johnson mathematics test, who in turn scored five points lower than children weighing 1501-2000g at birth (although the statistical significance of this difference is not reported). This was a similar finding to that of McGrath and Sullivan (2002), who found significant between group differences of up to one standard deviation. At age eight, their FT group (n = 37) scored nine points higher than the low birth weight group (n = 51), ten points higher than the very low birth weight group (n = 52), and 11 ½ points higher than those born extremely low birth weight (n = 48) on the standardised WRAT arithmetic subtest.

Development of Mathematical Cognition

Studies on typical mathematical development have identified a sequence through which children progress when they are learning to perform basic arithmetic tasks (Geary, 1993). These are: counting on their fingers, counting aloud – first counting all the numbers, then counting on from the largest number (for example, if asked "What is 2 + 5?", the child would say "5, 6… 7!"). These counting skills are generally acquired around the age of six or seven years. Once these counting skills are acquired and used often, associations between a problem and its solution are committed to memory, enabling a child to produce an answer from long-term memory. This mastery of basic fact retrieval is important for the acquisition of more complex mathematic strategies.

Children with MLD demonstrate problems progressing through this calculation process. Geary (2010) notes three categories of problems; deficits in the retrieval of arithmetic facts from long-term memory; deficits in the execution of procedures for solving simple arithmetic problems (e.g. 3 + 5); and a fundamental deficit in number sense. Children with memory retrieval problems have difficulty learning and/or remembering math facts and make more errors than peers, a difficulty that seems to persist throughout schooling. Children with procedural problems have difficulty executing calculation procedures and tend to use more immature strategies than their peers, however they seem to catch up with peers by age seven or eight. Children with a number sense deficit have difficulty understanding the exact quantity of small collections of objects (for example, recognising a group of three or four objects without counting them), and have a less precise representation of approximate magnitude for larger quantities (for example, recognising which image has more objects, when presented with two images with different amount of objects).

Understanding Mathematical Difficulties

As well as describing the underachievement of children born VPT, research must attempt to understand why this is the case, and once this is established, investigate the most effective ways to help these children improve their academic achievement. Researchers are beginning to investigate cognitive deficits and how these may be contributing to mathematical difficulties. Some researchers, for instance, have suggested that particular aspects of cognition (e.g. verbal and visuo-spatial working memory, spatial representation, visual reasoning, and self-regulatory function) are related to mathematical difficulties (Assel, Landry, Swank, Smith, & Steelman, 2003; Butterworth, 2005; Geary, Hamson, & Hoard, 2000; Geary, 2011; Holmes & Adams, 2006; Rousselle & Noel, 2007).

One area that seems to be especially important for mathematical achievement is executive function. Studies have identified the specific executive function skills of inhibiting (St Clair-Thompson & Gathercole, 2006; van der Sluis, de Jong, & van der Leij 2004), attentional shifting (Clark, Pritchard & Woodward 2010; Jenks, de Moor & van Lieshout, 2009), updating (Deschuyteneer, Vandierendonck & Muyllaert, 2006; Passolunghia & Pazzaliab, 2005), planning (Bull, Espy & Wiebe, 2008; Kroesbergen et al., 2009), monitoring (Bull, Espy & Wiebe, 2008) and working memory (Hecht, 2002; Swanson, 2006) as being key components that predict mathematical achievement.

Studies in typically developing populations have shown that problems in executive function can predict poor mathematical achievement later in life (Assell et al., 2003; Clark, Pritchard & Woodward, 2010). Conversely, executive function skills give children a head start in mathematical achievement (Bull, Espy & Wiebe, 2008). For example, Bull, Espy and Wiebe (2008), examined the relationship between performance on executive function tasks at age 4 years and mathematics performance at ages 5, 6 and 7 years, and found that working memory, inhibiting, planning and monitoring were related to mathematics achievement. Children who have difficulty with these executive functions will likely have difficulty with mathematics. Working memory is necessary for holding steps of calculations on line, inhibiting skills are required to disregard irrelevant information or inappropriate strategies, and shifting attention is needed to know which strategy to apply. Executive function skills play an important role in acquiring mathematical competence because children who are able to apply these strategies and develop sound knowledge of mathematical facts are then able to commit the facts to long-term memory, which in turn allows the development of more advanced mathematical strategies. (Geary, 1993).

Executive Function and Very Preterm Birth

Research concerning the cognitive correlates of mathematical difficulties in children born VPT has so far focussed on the basic components of cognitive functioning, including motor skills (Botting et al., 1998; Sullivan & McGrath, 2003), IQ and phonological processing skills (Breslau, Johnson & Lucia, 2001; Schneider et al., 2004), and visual-perceptual skills (Breslau, Johnson & Lucia, 2001). Little is known about the role of more advanced cognitive capacities, such as executive function. Executive functions are considered to be a set of processes that are important for managing oneself in order to achieve a goal (Gioia et al., 2002) and are important in emotional regulation, behaviour and cognitive functioning. There is general consensus that executive function represents a unifying construct, while also being an umbrella term for a range of specific component skills. Specific executive function processes include anticipation, goal selection, planning and organization, initiation of activity, self-regulation, mental flexibility, deployment of attention, working memory, and utilization of feedback (Anderson, 2002).

Executive function measures can be classified as clinical or ecological. Clinical measures typically used include puzzle-type tasks that a child completes under the direction of the clinician, such as the tower of London, the stroop test, and the trail making test. However, there is debate as to whether this type of assessment *actually* taps the latent construct in question, and if it *only* taps that construct (Friedman et al., 2006; Miyake et al., 2000). Furthermore, in the lab setting, the child has the benefit of the examiner, who structures and scaffolds the task and clarifies instructions, in a distraction-free room. Problems faced by children in real life situations are often far more complex than even the most difficult clinical assessment of executive function (Meltzer & Krishnan, 2007).

Ecological measures, on the other hand, rely on parent and teacher responses to questionnaires regarding behaviour that the child exhibits. This allows an assessment relevant to the environments in which the child is required to function. Agreement among different raters across different settings is considered to be a reliable measure of executive function. Widely used behaviour rating scales include the Behavior Rating Inventory of Executive Function (BRIEF) and Metacognitive Awareness System (MetaCOG). These questionnaires require parents and teachers to rate children on their behaviour and metacognitive ability, with questions such as “underestimates the time needed to finish tasks” and “does not give up when the work is difficult”.

Regardless of the measures used, studies have shown that children born VPT are at greater risk for executive dysfunction. For example, Anderson and Doyle (2004) administered a range of measures of specific executive functions, as well as the BRIEF parent questionnaire to 298 children with birth weights less than 1000g or born less than 28 completed weeks of gestation and 262 children born FT and weighing more than 2499g. Children in the extremely preterm group obtained lower scores than those born FT in measures of executive function, including shifting attention, initiating activities, working memory, planning and organization, organization of materials and self-monitoring.

Limitations of the Current Literature

The articles reviewed are not without limitations. Common limitations discussed below include inconsistency in grouping participants by birth weight or prematurity; lack of a suitable control group; small or unrepresentative samples; and high rates of attrition.

Sampling differences: Very preterm or very low birth weight. There is a lack of consistency in the studies reviewed in regards to whether participants are grouped according to weight at birth, or gestational age. Seven studies categorised groups according to birth weight, six used gestational age only and a further three studies categorised according to both birth weight and gestation (Table 1). Classification based on gestational age is preferable to grouping children according to birth weight. The latter is problematic because the sample may then also include infants born FT, but small for their gestational age, making the true effects of preterm birth difficult to see (Anderson & Doyle, 2003). The study by Chaudhari (2004) investigated mathematical achievement in a group of 180 children born low birth weight. Included in this low birth weight group were 33 children born FT. When defined by birth weight, children born 1500-2000g scored one quarter of a standard deviation below the control group, and children born less than 1500g scored one half of a standard deviation below the control group. When defined by prematurity, both preterm and FT children who were small for their gestational age scored about one third of a standard deviation below control children, while children born preterm but who were appropriate age for their gestation were only one quarter of a standard deviation below the control group. These results highlight the confounding effect that birth weight could have when investigating outcomes of very preterm birth, as children who are small for their gestational age are more at risk of poor outcomes than are children who are born preterm but at an appropriate weight for their gestational age.

In addition to inconsistencies in grouping by weight or gestation, variation exists in the classification of preterm groups. Those studies focusing on children born extremely preterm included children born either less than 28 weeks (Anderson & Doyle, 2003; Bowen, Gibson & Hand) or less than 25 weeks (Johnson et al., 2009). There was greater variation among definitions of very preterm, with some authors including children born less than 30 weeks gestation (Wocadlo & Rieger, 2007; Wocadlo & Rieger, 2008), less than 32 weeks (Chaudhari et al., 2004; Foulder-Hughes & Cooke, 2003), less than or equal to 33 weeks (Pritchard et al., 2009), or children born between 32-35 weeks gestation (Huddy, Johnson & Hope, 2001). Having a consistent definition of extremely preterm and very preterm would better serve parents and teachers of children born preterm, as the extent of difficulties faced by children in each group varies considerably according to extent of prematurity.

Use of controls. While the majority of studies included some form of term born control group, five studies failed to compare outcomes of children born VPT with a suitable control group (Huddy, Johnson & Hope, 2001; Pinto-Martin et al., 2004;Saigal et al., 2003; Wocadlo & Reigler, 2007; Wocadlo & Rieger, 2008). As random assignment to groups is not possible for studies of children born VPT, then results need to be interpreted with consideration to differences between groups. Ideally children should be matched for factors such as race, gender and socio-economic status (Hack, Klein & Taylor, 1995). Bowen, Gibson and Hand (2002) recruited a school-matched FT comparison group in order to better compare outcomes between children born VPT and children born FT. They matched 48 children born extremely preterm with 48 children born FT on age, gender and school. Children born extremely preterm were more likely to have lower scores in tests of mathematical ability and to perform at a level 12 months or more behind FT peers. Because children were matched for particular factors, the differences in outcomes can be attributed to being born VPT.

On the other hand, Pinto-Martin et al., (2004) examined school performance and the use of special education services in 645 children with low birth weight, and found that about one third of children with low birth weight require special education services, and that children born VPT are also at risk for low IQ, poor performance on standardised tests, and grade retention. As their study did not include a control group, it is impossible to know whether these outcomes are significantly poorer than, or are comparable to outcomes of children born FT.

Furthermore, having a comparison group is preferable to simply describing standardised norm outcomes, in order to show the nature and extent of difficulties encountered by children born VPT. This also avoids the potential for Flynn effects having an impact on data, whereby children would obtain a lower score when assessed on an older version of an intelligence test, and a higher score when using a newer version (Kanaya & Ceci, 2007).

Single hospital or regional cohort/ small sample size. Studies also differ in the size of their samples and where the samples were recruited from, with some obtained from a single hospital and other samples involving a regional cohort. Small sample size limits the generalisability of the results, and likewise, samples from a single hospital may be less representative of the whole population.

Four studies had groups with fewer than 65 participants (Bowen, Gibson & Hand, 2002; Huddy, Johnson & Hope, 2001; McGrath & Sullivan, 2002; Wocadlo & Rieger, 2007). For example, Huddy, Johnson and Hope (2001) analysed mathematical achievement in a total of 117 children born between 32 and 35 weeks. There were only 12 children in the 32-week group, 22 children in the 33-week group, 38 children in the 34-week group, and 45 children in the 35-week group. Results showed that 42% of children born at 32 weeks had poor mathematical outcomes, and 23% of children born at 33 weeks had poor mathematics performance. These results need to be interpreted with caution. It would be unwise to conclude that the rate of children with difficulty in mathematics almost doubles between 32 and 33 weeks, because the sample sizes for each of these groups are so small. A more accurate interpretation would be to combine all groups (as the authors do), and report that up to one third of children born preterm (less than 36 weeks) will likely have mathematical difficulties.

Attrition. All studies in this review are longitudinal follow-up studies, and therefore subject to attrition. There are varying rates of attrition reported, with about one third of studies encountering high rates. This causes concern as to whether the remaining children are representative of the whole population, especially as children lost to follow-up are more likely to be those who have poorer outcomes (Hack, Klein & Taylor, 1995). Attrition can particularly bias assessment of achievement, making it unrealistic to generalise all the findings of these studies to all children born VPT. In studies of children born VPT, non-attending children are more likely to have difficulties, resulting in an underestimation of impairment (Johnson et al., 2009).

In another example, Hagen et al., (2006) obtained WKCE scores for only 18% of eligible children (based on the original cohort of 803 who survived to age 5), and teacher report forms for 31.5% of children. They report that in mathematics ability, children born very low birth weight scored just below average and children born FT scored just above average as rated by teachers. They also found that more children born FT than children born very low birth weight are proficient or advanced in mathematics. These differences do not seem particularly large in light of the research previously mentioned, however differences might have been larger had the attrition rate been smaller, especially as children retained to age 10 years had a higher mean birth weight than the group of all children surviving to the same age. Furthermore, more children born very low birth weight than FT failed to sit the WKCE exam due to it being ‘inappropriate’ for the child’s ability. These issues suggest that had all eligible children been assessed, group differences in mathematical ability might have been more severe.

While it is important to acknowledge methodological shortcomings and ensure future research is conducted in a more uniform fashion, it would appear that these limitations tend not to exaggerate the difficulties of children born VPT rather, if anything, they serve to underestimate them. There is overwhelming evidence to show that children born VPT have had a difficult start to life and that these difficulties continue through the school years, impacting on learning and achievement in a wide range of areas, not least in mathematics.

Rationale for the Current Study

Little is currently known about the achievement of children born VPT in specific component areas of mathematics, or about potential mechanisms underlying the higher risk among children born VPT of poor mathematical achievement. This study aims to investigate these issues whilst attempting to circumvent the methodological definitions mentioned above that have limited previous studies. First, this study was based on a regional birth cohort followed from birth, allowing generalisation and reducing bias. A comparison group of children born FT was included in order to highlight the relative deficits of children born VPT. Second, very preterm classification of less than 33 weeks gestation was used in order to eliminate the potentially confounding effects of very low birth weight. Third, lab-based and classroom-based measures were used, as a multi-method approach to assessment is ideal. The standardised measure allows comparison with other studies, however an ecologically relevant measure (i.e. curriculum-based classroom test) was also conducted in order to show the nature of mathematical difficulties in children born VPT, including areas of strength and weakness, and to enable discussion of mathematics difficulties in a real world context. Fourth, the study also includes assessment of executive function skills, in order to investigate potential mechanisms underlying mathematics difficulty in children born VPT.

General Aims

1) To compare outcomes at age 9 years of children born very preterm and children born full term, in mathematical achievement and executive function.
2) To break mathematical achievement down into different components and examine the specific mathematics strategies and content knowledge that children born very preterm can and cannot do/know by age 9 years.
3) To examine the extent to which poor mathematical performance at age 9 years among children born very preterm can be explained by executive function skills at age 6 years, including inhibiting, shifting attention, emotional control, initiating, working memory, planning, organising materials and monitoring. Based on previous research, it is hypothesised that inhibiting, shifting attention, working memory, planning, and monitoring will be associated with mathematical achievement.

CHAPTER 2

METHOD

Participants

Study group. The study participants consisted of a birth cohort of children, now nine years old, who were born very preterm, and are participants in a larger longitudinal study. The sample includes 102 children born very preterm (less than 33 weeks gestational age) who were consecutively admitted to a level III neonatal intensive care unit at Christchurch Women's Hospital between November 1998 and December 2000. This neonatal service is the primary unit serving the greater Canterbury region of New Zealand. To be eligible for inclusion in this study, children had to be free from congenital abnormalities and have English speaking families. One hundred and nineteen children met this criteria and, excluding deaths (n = 10), 92% of all eligible children were recruited. At age nine years, 102 of the 109 survivors (94%) were available to participate in the follow-up assessment. This group is comprised of 43 children born extremely preterm (less than 28 weeks gestation) and 59 children born very preterm (28-32 weeks gestation).

Comparison group. One hundred and nine comparison children born full term (mean gestational age 40 weeks, range: 38-41 weeks gestation) were recruited at age two. These children were identified from hospital birth records (n = 7200 births) by selecting a same-sex child born two births before or after delivery of each child born very preterm. Of the 177 families identified, 113 (64%) agreed to participate. At nine years of age, 109 (96%) of those originally recruited participated in the follow-up assessment.

Procedures

Within two weeks of their ninth birthday, children attended a half-day assessment at a university-based clinic. This included a standardized test of mathematical performance (the

Woodcock-Johnson maths fluency test). Data regarding the child's achievement in mathematics was also obtained from each child's classroom teacher, including data from the numeracy project assessment, as well as teacher ratings of classroom achievement. At each assessment (i.e. 2, 4, 6, and 9 years) parents and teachers were asked to supply information about the child's executive function, using the Behavior Rating Inventory of Executive Function (BRIEF). Data from the 6-year assessment was used in this study as a predictor variable. All procedures and measures were approved by the Canterbury Regional Ethics Committee and written informed consent was obtained from all parents/caregivers. Measures included in this analysis are described below.

Measures

Clinic based measures of educational achievement. The Woodcock-Johnson III (WJ-III, Woodcock, McGrew, & Mather, 2001) maths fluency subtest is a timed pen and paper test that assesses children's ability to quickly and accurately complete addition and subtraction sums. Children were given six pages of single addition and subtraction sums to be completed in three minutes. Each page had 15 sums, to give a maximum of 90 sums. The format was altered slightly in order to better reflect the current practice in New Zealand schools. Sums were therefore presented horizontally (1 + 4 = _) instead of vertically. Test re-test reliabilities for the WJ-III are high (0.7 – 0.9) and test performance has been shown to correlate significantly with other measures of academic achievement, supporting the construct validity of this measure (Cizek, 2003).

WJ-III scores were then used to determine whether children had a mathematical learning disability (MLD), as defined by low achievement, whereby any child obtaining a score lower than one standard deviation below the mean of the FT group was categorised as having a mathematics learning disability (16^{th} percentile cutoff).

Teacher ratings of educational achievement. Children's teachers were sent a questionnaire booklet (see Appendix 1) asking them to rate the child's general school progress in mathematics and numeracy on a scale of 1 (*delayed*) to 5 (*advanced*) relative to their classroom peers. Ninety-five per cent of teacher questionnaires were returned for children born VPT and 90% for children born FT. Teachers were also asked to rate the child's progress in several different areas of mathematics. These questions (Section B in Teacher Questionnaire) were based on Geary's (2004) proposed three subtypes of learning disabilities in mathematics; delay in acquiring simple arithmetic strategy (5 questions), deficit in retrieval of facts (4 questions), and deficits in the spatial representation of number (3 questions), and required teachers to rate the child on a scale from 1 (*unable*) to 5 (*advanced*). In addition to these questions, there were nine additional questions relating to components of mathematics learning difficulties, for which teachers were asked to use a 3-point scale (1 = *much difficulty*, 3 = *no difficulty*) to rate the child's ability.

National curriculum-based measures of educational achievement. Teachers were also asked to provide results from the numeracy project assessment (Ministry of Education, 2004). The numeracy project assessment is a curriculum-based measure widely used in New Zealand schools. It involves a one-on-one diagnostic interview (see Appendix 2) that assesses the child's developmental stage in three strategy domains (addition/subtraction, multiplication/division, proportions/ratios) and four knowledge domains (number identification, number sequence and order, grouping and place value, basic facts). Teachers ask between 3 and 22 questions for each concept, and performance on each task is recorded as a stage score from 0 to 8. A child in strategy stage 0 is able to count in sequence but lacks the knowledge of 1-to-1 correspondence. Stages 1 to 4 are based on counting strategies, beginning with counting on objects (e.g. fingers) and progressing to mentally counting on from the last digit. A child in stages 5 to 8 is able to use part-whole strategies, characterised by children knowing that numbers can be broken down into smaller units, manipulated and reformed, in order to add, subtract, multiply and divide. A 9-year-old child would be expected to be achieving at stage 5 (Tagg & Thomas, 2007). The numeracy project can be seen to assess two of the three subtypes of learning difficulty proposed by Geary

(2010). If children show a delay in developing sound problem-solving strategies (i.e. in addition/subtraction, multiplication/division, proportion/ratio) they may fit into Geary's procedural deficit subtype. If they show difficulties with the factual knowledge components of the numeracy project (i.e. number identification, number sequence, group/place value, basic facts), they may fit the semantic memory subtype of mathematical learning difficulty. Numeracy project data was collected for 78% of children born VPT, and 77% of children born FT.

Measures of executive function. Following children's clinic-based assessment at age 6-years, their teachers were sent a questionnaire regarding their behaviour at school. As part of this questionnaire, The Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) was used to assess executive function behaviours in the everyday context of the school environment. Parents were also asked to complete the parent version. A composite score was calculated by summing the teacher and parent t-score for each subscale, and dividing this by two. The BRIEF is an 86-item, standardized checklist. Items such as, "Is upset by a change in routine," or "has trouble putting the brakes on actions even after being asked," are rated on a three point likert scale. Scores are summed to create composite indices of inhibitory control, shifting, initiating, working memory, emotional regulation, monitoring, organization and planning. Test-re-test reliabilities for the BRIEF are high (0.82 for parents, 0.88 for teachers) and internal consistencies are also high (0.80-0.98) (Meltzer & Krishnan, 2007).

Family social background characteristics. A range of measures were collected to describe the family circumstances of children in the study. Measures included maternal age and socioeconomic status. Maternal age refers to the age in whole years of the mother when she gave birth to the study child. Socioeconomic status at the time of the child's birth was assessed using the New Zealand census-based Elley-Irving Socioeconomic Index (Elley & Irving, 2003). This scale categorises families into six classes on the basis of occupation ranging from 1 = professional to 6 = unskilled occupation. Data from the parent with the lowest score was used, to give a measure of maximum socioeconomic status for each family.

CHAPTER 3

RESULTS

Clinical and Social Background Characteristics of Very Preterm and Full Term Children

Table 2 shows the clinical and family social background characteristics of children in the two study groups. Significant between group differences were found on measures of gestational age at birth ($p < .001$), birth weight ($p < .001$), multiple birth ($p < .001$), and intrauterine growth restriction (IUGR; $p = .002$). There were no differences in the gender composition of the two groups. In regards to the family social backgrounds of the children in the study, children in the very preterm (VPT) group were more likely than full term (FT) children to be of European ethnic background ($p = .048$), of lower SES ($p < .001$), and to have been born to a mother who smoked during pregnancy ($p = .001$). There were no differences in maternal age or family composition across the two groups. In terms of their neurodevelopmental status, children born VPT were more likely than FT children to have been diagnosed with cerebral palsy (CP; 13.5% vs. 1%), to have a lower IQ ($p < .001$), and to meet criteria for severe cognitive delay ($p = .039$), as defined by having an IQ score more than two standard deviations below the mean of the FT group.

Table 2
Sample Characteristics

Measure	FT (N=108)	VPT (N=102)	Cohen's *d* / odds ratio	95% CI LL	UL	*P*
Clinical Characteristics						
Mean (SD) gestation (weeks)	39.5 (1.2)	27.8 (2.4)	6.93			< .001
Mean (SD) birth weight (g)	3580 (411)	1050 (316)	6.53			< .001
% Male	54.1	50	0.85	0.49	1.46	.55
% Twin	3.9	34.7	13.02	4.41	1.71	< .001
% IUGR[a]	0.9	10.8	13.06	1.65	103.05	.002
Mean (SD) days on oxygen	-[b]	42.4 (50.8)				< .001
% IVH/PVL[c]	-[b]	8.8				.002
% Postnatal steroid exposure	-[b]	10.8				< .001
Family Social Background Characteristics						
Mean (SD) maternal age	31.1 (4.6)	30.7 (5.3)	0.08			.60
% European ethnicity	80	90.2	2.31	0.99	5.37	.048
Mean (SD) max SES	3.07 (1.31)	3.83 (1.62)	-0.58			< .001
% Single parent	11.2	17.8	0.58	0.27	1.28	.18
% Smoking	15.3	37.2	3.28	1.65	6.55	.001
Neurodevelopmental Impairment						
% Any cerebral palsy	1	13.5	16.92	2.17	131.92	< .001
Mean (SD) FSIQ[d]	104 (12)	94 (14)	0.80			< .001
% Severe cognitive delay	2.8	9.8	3.76	0.99	14.33	.039

[a] IUGR=intrauterine growth restriction.
[b] Cells are empty because no children born FT required these interventions or had IVH/PVL.
[c] IVH= intraventricular haemorrhage, PVL= periventricular leukamalacia.
[d] FSIQ=Full Scale Intelligence Quotient.

Mathematical Outcomes of Very Preterm and Full Term Children

Clinically based tests of mathematical achievement. Table 3 shows the mean scores and standard deviations for the VPT and FT groups on the WJ-III maths fluency subtest. Between group differences were examined using an independent sample t-test and the effect size using Cohen's *d*. Children born VPT obtained on average lower scores than FT children on the WJ-III maths fluency subtest ($t(205) = 4.44$, $p < .001$). Furthermore, a third of children born VPT were categorised as having a mathematical learning disability, defined as obtaining a score more than one standard deviation below the mean of the FT group, compared to nearly 15% of children in the FT group ($p = .002$).

Table 3
Mathematical Outcomes

Measure	FT	FT n	VPT	VPT n	Cohen's *d* / odds ratio	95% CI LL	95% CI UL	*p*
Clinical Assessments								
Mean (sd) WJ-III[a] math fluency	48.9 (16.8)	108	38.5 (16.9)	99	0.62			<.001
% MLD[b]	14.8	108	33.3	99	2.86	1.47	5.56	.002
Teacher Rating: below average								
% Mathematics	22.9	96	49.5	97	3.33	1.79	6.25	<.001
% Numeracy	21.6	97	52.6	97	4	2.13	7.69	<.001
Mean (SD) Numeracy Project Assessment								
Addition/subtraction	5.18 (.98)	83	4.75 (1.14)	80	0.40			.002
Multiplication/division	5.11 (1.03)	76	4.52 (1.28)	79	0.51			<.001
Proportion/ratio	4.67 (1.17)	69	4.35 (1.14)	68	0.28			.049
Number identification	5.19 (.82)	63	4.87 (1.02)	70	0.35			.006
Number sequence	5.03 (.99)	68	4.85 (1.04)	73	0.18			.072
Place value/group	4.89 (.99)	70	4.58 (1.11)	72	0.29			.009
Basic facts	4.96 (1.1)	73	4.59 (1.25)	73	0.31			.006

[a] WJ-III = Woodcock Johnson tests of achievement.
[b] MLD = Mathematical Learning Difficulty

Teacher ratings. Further analysis of children's ability in mathematics and numeracy based on teacher reports revealed clear differences between children born VPT and children born FT. As shown in Table 3, children born VPT were more than twice as likely as FT children to be achieving at a below average level in both mathematics ($p < .001$) and numeracy ($p < .001$) according to teacher perceptions.

Further examination of more specific mathematical components (Section B of the Teacher Questionnaire) was conducted in order to determine if children born VPT were likely to show difficulties across all areas, or whether specific difficulties exist. The 21 items of Section B of the Teacher Questionnaire were subjected to principal components analysis (PCA) using SPSS version 19. Prior to performing PCA, the suitability of the data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of .3 and above. The Kaiser-Meyer-Olkin value was .909, exceeding the recommended value of .6

(Kaiser 1970, 1974) and Bartlett's Test of Sphericity (Bartlett 1954) reached statistical significance, supporting the factorability of the correlation matrix.

Results are displayed in Table 4. Principal components analysis revealed the presence of four components with eigenvalues exceeding 1, explaining 46.5%, 21.6%, 5.7% and 5.4% of the variance respectively. Inspection of the scree plot revealed a clear break after the second component. Using Catell's (1966) scree test, it was decided to retain two components for further investigation. The two-component solution explained a total of 68.0% of the variance, with component 1 contributing 46.46% and component 2 contributing 21.57%. To aid in the interpretation of these two components, oblimin rotation was performed. The rotation solution revealed the presence of simple structure, with both components showing a number of strong loadings and all variables loading substantially on only one component. Component 1 appears to be mathematical skills, which are all loading together and not differentiating between sub-components, and Component 2 appears to be spatial skills. Overall, the outcome of the PCA was not very informative, and therefore these questions were not used in any further analysis.

Table 4

Pattern and Structure Matrix for PCA with Oblimin Rotation of Two-Factor Solution of Teacher Questionnaire Items

Item	Pattern Coefficients		Structure coefficients		Communalities
	Component 1	Component 2	Component 1	Component 2	
Understand relationships between numbers	**.897**	.015	**.896**	-.049	.804
Recalls steps needed in word problems	**.894**	.039	**.891**	-.025	.796
Correct calculations used to solve problems	**.888**	.016	**.886**	-.047	.786
Sort important from extraneous information	**.875**	-.007	**.875**	-.069	.766
Retrieve basic math rules	**.872**	.019	**.871**	-.043	.759
Tell which of two numbers is largest	**.867**	.017	**.865**	-.045	.749
Implement a plan to solve problems	**.861**	-.008	**.862**	-.069	.743
Learn basic math rules	**.861**	.015	**.860**	-.046	.739
Remember what symbols mean	**.859**	.003	**.859**	-.058	.738
Work through multiple steps in word problems	**.851**	-.025	**.853**	-.086	.728
Use mental counting strategies	**.809**	-.012	**.809**	-.070	.655
Identify signs and their meanings	**.684**	-.055	**.688**	-.104	.476
Work with number sets	**.594**	.068	**.589**	.026	352
Correctly align numbers when copying	**.545**	.017	**.544**	-.022	.296
Place numbers in correct columns when solving an equation	**.456**	.012	**.455**	-.020	.207
Conceptualise time	**.351**	-.073	**.356**	-.098	.132
Differentiate left and right	-.015	**.991**	-.087	**.992**	.984
Estimate the size of an object	-.015	**.991**	-.085	**.992**	.983
Navigate a map	-.016	**.990**	-.086	**.992**	.983
Distinguish north, south, east, west	-.016	**.990**	-.086	**.992**	.983
Estimate distance	.050	**.792**	-.006	**.789**	.625

Note: major loadings for each item are bolded.

Performance on curriculum based tests. Results from the numeracy project assessment are reported in Table 3. Because children spanned a number of school years (Years 4 - 7), an ANCOVA was conducted for each of the numeracy project subtests, with Year at School entered as a covariate. Children born VPT performed less well than FT children across all subtests except number sequence. With the exception of this last subtest, children born VPT scored one-third to one-half a stage behind children born FT. The greatest difference occurred in the multiplication/division subtest, where children born VPT were on average more than half a stage behind children born FT ($p < .001$). Cohen's effect size value ($d = .51$) suggested a moderate practical significance.

In a second analysis, based on their score for each numeracy project subtest, all children were classified as achieving 'at or above' or 'below' the national norms for each subtest. The percentage of children in each group performing below the national norm was calculated and analysed using a chi-squared test of independence. It is important to note that numbers of participants in each subtest vary due to the inconsistent nature of data collection across different schools. Nonetheless, despite reduced sample numbers for these analyses across the range of numeracy project subtests, results in Table 5 reveal clear between group differences. Between one and a half and three times as many children born VPT, compared to those born FT, were performing at a level below the national norm in the multiplication/division (38% vs. 17%), number identification (24% vs. 9%), number sequence (26% vs. 13%) and place/group (34% vs. 17%) subtests.

Table 5

Percentage of Children Performing Below National Norm in the Numeracy Project Assessment

Subtest	FT %	FT n	VPT %	VPT n	Odds ratio	95% CI LL	95% CI UL	*p*
Addition/subtraction	12.0	83	23.5	81	0.45	0.19	1.03	.056
Multiplication/division	16.5	79	38.0	79	0.32	0.15	0.68	.002
Proportion/ratio	20.3	74	31.5	73	0.55	0.26	1.17	.120
Number identification	9.1	66	24.3	70	0.31	0.12	0.85	.018
Number sequence	12.9	70	26.0	73	0.42	0.18	1.00	.047
Place value/group	16.9	71	33.8	74	0.40	0.18	0.88	.020
Basic facts	19.2	73	32.0	75	0.50	0.24	1.08	.074

Socioeconomic Status

Due to the over-representation of lower socioeconomic status (SES) families in the very preterm group, the above analyses were run again including SES as a covariate, in order to assess the extent to which between group differences might, either in part or in full, reflect the confounding effects of family SES on school achievement. Results in Table 6 show that differences in performance on the WJ-III maths fluency subtest and teacher rating of mathematics and numeracy ability remained significant after adjustment for SES. For achievement on numeracy project subtests, between group differences persisted only for addition/subtraction and multiplication/division. Numeracy project subtests rendered insignificant by including SES as a covariate were therefore not included in subsequent analyses.

Table 6
Mathematical Outcomes, Controlling for SES

Measure	Unadjusted mean (SD)		Adjusted Mean (SE)		Mean difference	95% CI		*p*
	FT	VPT	FT	VPT	(SE)	LL (for difference)	UL	
Mean (sd) WJ-III[a] math fluency	48.9 (16.8)	38.5 (16.9)	50.1 (2.0)	38.6 (1.8)	11.5 (2.8)	6.00	16.98	< .001
% Math learning difficulty	14.8	33.3	16.6	30.9	-	-	-	.026
% Below average mathematics	22.9	49.5	23.6	51.6	-	-	-	< .001
% Below average numeracy	21.6	52.6	22.6	55.3	-	-	-	< .001
Mean (SD) addition/subtraction	5.18 (0.98)	4.75 (1.14)	5.17 (0.12)	4.78 (0.12)	0.39 (0.17)	0.05	0.74	.025
Mean (SD) multiplication/division	5.11 (1.03)	4.52 (1.28)	5.12 (0.14)	4.54 (0.13)	0.58 (0.20)	0.19	0.97	.004
Mean (SD) proportion/ratio	4.67 (1.17)	4.35 (1.14)	4.69 (0.15)	4.36 (0.14)	0.33 (0.21)	-0.09	0.74	.120
Mean (SD) number identification	5.19 (0.82)	4.87 (1.02)	5.19 (0.12)	4.89 (0.11)	0.30 (0.17)	-0.03	0.64	.077
Mean (SD) number sequence	5.03 (0.99)	4.85 (1.04)	5.03 (0.13)	4.87 (0.12)	0.16 (0.18)	-0.19	0.50	.374
Mean (SD) place value/group	4.89 (0.99)	4.58 (1.11)	4.91 (0.13)	4.57 (0.13)	0.34 (0.19)	-0.03	0.71	.072
Mean (SD) basic facts	4.96 (1.1)	4.59 (1.25)	4.98 (0.14)	4.59 (0.14)	0.38 (0.20)	-0.02	0.79	.062

[a] WJ-III = Woodcock Johnson tests of achievement.

Severe Neurodevelopmental Impairment

A further issue that needs to be considered is the extent to which the above findings might reflect the poor educational performance of a subset of children with severe neurodevelopmental impairment (NDI). To examine this, further analyses were conducted excluding children who had a diagnosis of cerebral palsy (CP) and/or severe cognitive delay (Table 7). Severe cognitive delay was defined as FSIQ score more than two standard deviations below the mean FSIQ score of the FT group, which in this study means children were excluded if they had an IQ score of less than 80.

Table 7
Mathematical Outcomes, Excluding Children with Neurodevelopmental Impairment

Measure	FT	FT n	Very Preterm: no NDI	Very Preterm: no NDI n	Cohen's d/ odds ratio	95% CI LL	95% CI UL	*p*
Clinical Assessments								
Mean (sd) WJ-III[a] math fluency	49.82 (16.02)	105	42.27 (15.32)	79	0.49			.001
% Math learning difficulty	13.3	105	25.6	78	0.45	0.21	0.95	.034
Teacher Rating								
% Below average mathematics	20.4	93	45.3	75	0.31	0.16	0.61	.001
% Below average numeracy	19.1	94	49.3	75	0.24	0.12	0.48	<.001
Numeracy Project Assessment								
Mean (SD) add/sub	5.26 (0.88)	80	5.03 (0.92)	62	0.26			.029
Mean (SD) mult/div	5.15 (0.97)	75	4.73 (1.15)	63	0.39			.003

[a] WJ-III=Woodcock Johnson tests of achievement.

Table 7 shows the mean and standard deviation scores for the WJ-III maths fluency subtest and numeracy project subtest achievement levels, and the percentage of children rated by their classroom teachers as performing below average in curriculum-based mathematics and numeracy skills. Even after excluding children with CP or cognitive delay, between group differences remained for performance in WJ-III maths fluency subtest (p = .001), teacher rating of mathematics ($p = .001$) and numeracy achievement ($p < .001$), and the numeracy project addition/subtraction ($p = .03$) and multiplication/division ($p = .003$) subtests.

Despite showing clear between group differences when the mean stage for each numeracy project subtest was analysed, statistical significance was attenuated when children with NDI were removed from the sample in a second set of analyses that classified children as performing below the national norm (see Table 8). The only subsequent areas of significant difference remaining were in the subtests of multiplication/division (31.7% vs. 15.4%) and number identification (18.2% vs. 6.3%), where children born VPT were two to three times more likely to perform at a level below the national norm than children born FT. Despite the loss of significance, children born VPT showed a trend towards achievement below the national norm at a rate of one and a half to three times that of children born FT.

Overall, these results show that regardless of whether a child born VPT has CP/cognitive delay or not, they are nonetheless more likely than a child born FT to have difficulty in mathematics, whether using standardised educational measures in a research setting or more ecologically valid school-based measures such as teacher report.

Table 8
Percentage of Children Performing Below National Norm in the Numeracy Project Assessment, Excluding Children with Neurodevelopmental Impairment

Subtest	FT %	FT n	VPT %: no NDI	VPT: no NDI n	odds ratio	95% CI LL	95% CI UL	*p*
Addition/subtraction	8.8	80	15.9	63	0.51	0.18	1.42	.191
Multiplication/division	15.4	78	31.7	63	0.39	0.17	0.88	.021
Proportion/ratio	19.2	73	25.9	58	0.68	0.30	1.56	.360
Number identification	6.3	63	18.2	55	0.31	0.09	1.04	.047
Number sequence	9.1	67	20.7	58	0.38	0.13	1.08	.062
Place value/group	14.7	68	23.7	59	0.55	0.23	1.36	.195
Basic facts	15.7	70	23.3	60	0.61	0.25	1.48	.272

Note. There were 3 FT children and 20 VPT children with NDI.

Executive Functioning of Very Preterm and FT Children

Performance on BRIEF at age 6. An independent-samples t-test was conducted to compare the BRIEF scores at age 6, for children born VPT and FT. Table 9 reveals significant between-group differences ($p < .05$) for the inhibiting, shifting, emotional control, initiating, working memory, planning and monitoring subscales of the BRIEF, but no significant difference in the organising materials subscale ($p = .49$). Children born VPT obtained higher scores than their FT peers for all subscales of the BRIEF questionnaire, indicating that children born VPT are more likely than FT children to experience difficulties across all areas of executive function. Closer inspection of Cohen's effect size revealed a medium to large practical significance for initiate, planning, and monitor, a medium effect for shift and working memory, and a small to medium effect for inhibit and emotional control (see Table 9).

Table 9
Composite T-Scores for the BRIEF Questionnaire at Age 6 Years

Subscale	FT (n=103)	VPT (n=94)	Cohen's *d*	*p*
Inhibit	50.7 (7.6)	53.3 (7.8)	-0.33	.007
Shift	49.9 (7.6)	54.7 (10.0)	-0.54	< .001
Emotional control	51.3 (8.4)	53.9 (8.6)	-0.30	.034
Initiate	48.1 (7.3)	53.0 (8.5)	-0.62	< .001
Working memory	50.4 (10.3)	55.9 (11.9)	-0.49	.001
Planning	49.9 (7.8)	55.5 (9.5)	-0.64	< .001
Organising materials	53.1 (7.4)	53.8 (8.2)	-0.10	.49
Monitor	46.9 (7.8)	52.0 (9.1)	-0.60	< .001

Associations between executive functions at age 6 years and later mathematical achievement of children born very preterm. In order to determine the extent to which difficulties with executive function skills can explain subsequent difficulties with mathematical performance, a multiple regression was run. First, however, it was necessary to investigate correlations between the executive function and mathematical achievement measures. Table 10 shows the correlations between VPT children's' performance on the BRIEF questionnaire obtained at age 6 years and their subsequent performance on numeracy project subtests at age 9 years. Correlations were generally in the moderate range (*rs* = .27 - .60), suggesting continuities in performance across these measures.

Table 10
Associations Between VPT Children's Executive Function Performance at Age 6 Years and Mathematics Achievement at Age 9 Years

	Inhibition	Shifting	Emotional Control	Initiating	Working memory	Planning	Organise materials	Monitor
Addition/subtraction	-.35**	-.42**	-.34**	-.40**	-.50**	-.47**	-.36**	-.38**
Multiplication/divide	-.32**	-.33**	-.31**	-.27*	-.42**	-.34**	-.30*	-.29*
Proportion/ratio	-.33**	-.45**	-.41**	-.38**	-.58**	-.48**	-.43**	-.45**
Number ID	-.40**	-.34**	-.36**	-.32*	-.56**	-.41**	-.46*	-.38**
Number sequence	-.39**	-.36**	-.38**	-.34**	-.55**	-.43**	-.43**	-.39**
Group/place value	-.36**	-.36**	-.38**	-.36**	-.55**	-.44**	-.39**	-.34**
Basic facts	-.39**	-.47**	-.45**	-.38**	-.60**	-.50**	-.42**	-.41**

* $p < .05$. ** $p < .01$.
Note: n = 61 – 72

Relationships between VPT children's executive function performance at age 6 years and mathematics achievement at age 9 years. Hierarchical multiple regression was used to assess the ability of executive function, as measured at age 6-years by the eight BRIEF subscales (inhibit, shift, emotional control, initiate, working memory, planning, and monitor) to predict levels of mathematical achievement, at age nine years, on the seven numeracy project subtests, after controlling for the influence of year at school and SES. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity. Year at school and SES were entered at Step 1 and executive function measures for each numeracy project subtest were entered at Step 2. Standardised (beta) coefficients are presented in Table 11. For ease of reading, only values reaching statistical significance are shown. The basic model of year at school and SES explained between 15.7% and 24.6% of the variance in the scores of the numeracy project subtests. When executive function scores were added to the model, the total variance explained rose to between 43.5%and

66.8%. As expected, year at school was significant in all cases. Working memory and SES were significant predictors of mathematical achievement in all numeracy project subtests, with working memory making the strongest unique contribution to explaining the variance in each. Beta values were between -.48 ($p = .024$), and -.94 ($p < .001$) for working memory and between -.28 ($p = .006$) and -.33 ($p = .001$) for SES. Other executive functions making a significant contribution to the variance include initiating as a significant predictor for number identification (beta = .41, $p = .018$) and basic facts (beta = .37, $p = .02$); inhibiting as a predictor for ratio/proportion (beta = .45, $p = .013$); and organising materials as a predictor for number identification (beta = .35, $p = .008$). The BRIEF subtests of shifting attention, emotional control, planning and monitoring did not significantly predict mathematical achievement.

Table 11
Beta Values Showing Relationships Between VPT Children's Executive Function Performance at Age 6 Years and Mathematics Achievement at Age 9 Years

	Year at school	SES	Working memory	Inhibition	Initiation	Organise materials
Addition/subtraction	.34**	-.33**	-.48*			
Multiplication/division	.39**	-.31**	-.53*			
Proportion/ratio	.33**	-.29**	-.81**	.45*		
Number identification	.36**	-.29**	-.94**		.41*	-.35**
Number sequence	.35**	-.28**	-.81**			
Group/place value	.39**	-.31**	-.85**			
Basic facts	.39**	-.32**	-.85**		.37*	

* $p < .05$. ** $p < .01$.
Note. N = 61 – 72.

Executive function and mathematical achievement of children born very preterm, excluding children with severe neurodevelopmental impairment. As previously discussed, it was necessary to rule out the possibility that NDI could partially explain poor performance in mathematics, therefore the above regressions were run again, excluding children with NDI. Upon inspecting the correlation between executive function and mathematical achievement, it was discovered that correlations were lower when children with NDI were excluded (*rs* = .03-.54), and many failed to reach statistical significance (Table 12).

Table 12
Associations Between VPT Children's Executive Function Performance at Age 6 Years and Mathematics Achievement at Age 9 Years, Excluding Children with NDI

	Inhibition	Shifting	Emotional control	Initiating	Working memory	Planning	Organise materials	monitoring
Addition/subtract	-.28	-.10	-.20	-.17	-.30*	-.26	-.27	-.24
Multiply/divide	-.32*	-.11	-.27	-.17	-.31*	-.23	-.26	-.21
Proportion/ratio	-.36*	-.26	-.40**	-.33*	-.54**	-.39*	-.46**	-.42**
Number ID	-.31*	-.06	-.26	-.21	-.41**	-.21	-.34*	-.21
Number seq.	-.33*	-.08	-.28	-.23	-.40**	-.26	-.29	-.28
Group/place	-.33*	-.03	-.32*	-.22	-.39*	-.27	-.27	-.24
Basic facts	-.36*	-.24	-.43**	-.25	-.49**	-.38*	-.34*	-.37*

* $p < .05$. ** $p < .01$.
Note. n = 42 - 50

Based on the correlation matrix, the regression was performed including only the variables that had significant correlations of over .3. Results of the regression reaching statistical significance are presented in Table 13. The basic model of year at school and SES explained between 19.3% and 31.3% of the variance in the scores of numeracy project subtests. When relevant executive function scores (i.e. correlations over .3) were added to the model, the total variance explained rose to between 33.7% and 59.8%. SES continued to be a significant predictor in all numeracy project subtests. After excluding children with NDI, working memory was a predictor of mathematical achievement in all numeracy project subtests except multiplication/division and group/place value. In each case working memory continued to make a stronger unique contribution than SES to explaining the variance, except in addition/subtraction where SES and working memory made the same contribution. Beta values were between -.34 (p = .009), and -.75 (p = .003) for working memory and between -.33 (p = .012) and -.40 (p = .001) for SES. All other executive functions were no longer able to predict mathematical performance in children born very preterm.

Table 13

Beta Values Showing Relationships Between VPT Children's Executive Function Performance at Age 6 Years and Mathematics Achievement at Age 9 Years, Excluding Children with NDI

	Year at school	SES	Working memory
Addition/subtraction	.40**	-.34**	-.34**
Multiplication/division	.42**	-.34**	
Proportion/ratio	.39**	-.36**	-.75**
Number identification	.49**	-.38**	-.48*
Number sequence	.46**	-.37**	-.49**
Group/place value	.47**	-.33*	
Basic facts	.47**	-.40**	-.58*

* $p < .05$. ** $p < .01$.

Note. n = 42 – 50.

CHAPTER 4

DISCUSSION

Research concerned with the mathematical achievement of children born VPT has been largely restricted to general mathematical achievement, with few studies investigating specific component skills of mathematics that may be compromised by preterm birth. The present study sought to analyse the relative areas of strengths and difficulties in mathematics of children born VPT, compared to children born FT. Of further interest was the extent to which the poor mathematical performance of children born VPT could potentially be explained by deficits in executive function.

Summary of Findings

The key findings of this study can be summarised as follows: 1) Children born VPT consistently score lower than FT children on measures of general mathematical ability, whether measured by clinic- or school-based assessments. 2) Children born VPT have higher rates of mathematical learning disabilities (MLD) than FT children, even after excluding children with neurodevelopmental impairment (NDI) from analysis. This provides support for the presence of a specific maths learning disability among children born VPT, rather than their mathematics underachievement simply reflecting low IQ. 3) Children born VPT show significant difficulty using strategies in addition/subtraction and multiplication/division tasks, even after SES and NDI are controlled for. There appear to be no differences between children born VPT and FT in knowledge components (e.g. number facts). This suggests children have acquired the necessary knowledge for solving problems, but are unable to apply the knowledge to solving problems in the addition/subtraction and multiplication/division domains. 4) Children born VPT have more difficulty in almost all areas of executive function, as measured by the BRIEF parent/teacher rating scale, except organising materials. After controlling for SES and severe NDI, working memory was also significantly associated with all numeracy project subtests except multiplication/division and group/place value.

Mathematical Achievement

Consistent with previous research, results from this study indicate that children born VPT are more likely than their FT peers to have difficulty in mathematics, and to obtain lower scores than children born FT. These between group differences were evident across measures, whether clinic-based assessments, curriculum-based assessments, or teacher rating, and medium to large effect sizes were noted.

Children born VPT were more likely than FT peers to obtain lower scores on the WJ-III maths fluency test. This result was supported by teacher ratings of mathematics as a school subject, and teacher ratings of everyday numeracy. The poorer mathematical performance of children born VPT remained significant even after controlling for SES and excluding children with CP and/or severe cognitive delay. Results from these measures of general mathematic ability are consistent with the current literature. For example, in a study of 280 eight-year-old children born VPT, Foulder-Hughes and Cooke (2003) found that these children scored significantly lower than children born FT on the WISC test of general arithmetic ability. Likewise, Hagen et al. (2006) obtained teacher report forms detailing the mathematical achievement of 313 children born very low birth weight and found that teachers rated these children as having more difficulty with mathematics than children in the control group. The effect sizes in both these studies were of small to medium practical significance.

The current study adds weight to the argument that children born VPT may have cognitive scores in the broadly average range, but have higher rates of MLD than their term-born peers. This was demonstrated by significantly more children born VPT than FT being classified as having a MLD, a result that remained significant after controlling for SES and excluding children with CP and/or severe cognitive delay. Other studies with children born VPT have also noted that MLD is more common among this population, compared with children born FT. For example, in their study of 86 six-year-old children born VPT who did not have severe cognitive delays, Pritchard et al. (2009) found that these children were twice as likely as children born FT to meet criteria for MLD.

In terms of specific mathematics components, preliminary analyses revealed significant between group differences for all numeracy project subtests, however after controlling for SES only addition/subtraction and multiplication/division remained statistically significant. These results show that VPT children's difficulties lie with areas of mathematics requiring the selection and application of strategies, rather than factual knowledge. Furthermore, these results provide evidence for children born VPT having a procedural deficit subtype of mathematical learning disability (Geary, 2011). Children with procedural difficulties are delayed in their acquisition of problem-solving approaches, use more immature strategies and make more errors compared to typically achieving children. For example, children with procedural difficulties may continue to count on their fingers instead of counting in their head, or they may subtract the larger number from the smaller one (e.g. 83 – 44 = 41). Geary (2011) hypothesizes that these delays are related to working memory deficits, which will be discussed in the next section.

The reduction of significance of between group differences in mathematical achievement after controlling for SES in the current study is consistent with existing literature that has found SES to partially account for differences in mathematics ability. For example, Schneider et al. (2004) found that SES has an impact on mathematics performance above and beyond preterm birth, but note that its effects are similar for children born VPT and FT. The practical implication of this is that children born VPT from families of low SES may be at double jeopardy for poor mathematical performance.

In addition to SES partially accounting for differences in mathematical achievement, it could also be argued that children born VPT have more difficulty with mathematics than their full term peers, due to an overrepresentation of children with low IQ and neurodevelopmental difficulties. However, even after excluding those children with CP or severe cognitive delay from analysis, results show that children born VPT continue to obtain lower scores than FT children in the numeracy project subtests of addition/subtraction and multiplication/division. When children were classified as performing below the national norm, only the multiplication/division and number identification subtests remained significant after excluding children with CP and/or severe cognitive delay. However, although not significant, further investigation of the percentage of children in each group who were achieving below the national norm for each numeracy project subtest indicates that children born VPT are between 1 ½ to 3 times more likely than FT children to be achieving below the national norm. One possible explanation for the lack of statistical significance is that the analyses of children performing below the national norm are likely to be underpowered due to a small sample size.

One of the aims of this study was to separate mathematics into specific areas in order to investigate whether children born VPT have particular areas of strength and weakness. Section B of the Teacher Questionnaire contained questions relating to three subtypes of MLD - delay in acquiring simple arithmetic strategy; deficit in retrieval of facts; and deficits in the spatial representation of number. However principal component analysis unfortunately showed that these three question types loaded together rather than separately. One reason for this could be issues with this measure; for example it had not been used before, and therefore did not have established validity or reliability, and there may have been too few items for each subtype. Another reason could be that some teachers may have not read all the questions thoroughly or felt that they had such detailed knowledge of the child's skills and therefore simply scored the child similarly for all questions. This might particularly be the case if the teacher had not taught, assessed or observed a behaviour (for example, 'distinguish north, south, east, west' or 'conceptualise time and judge the passing of time'). In future efforts, including more items for each subtype may result in a more clear separation into the three subtypes.

Executive Function

Not only do children born VPT have more difficulties in mathematics, they also have more difficulties in executive function skills, as evidenced by their higher scores for almost all subscales of the BRIEF measure, with the exception of organising materials. There was also a predictive relationship found between working memory at age six and mathematical achievement at age nine in children born VPT. This predictive relationship between working memory and mathematical achievement was found in all numeracy project subtests except multiplication/division and group/place value.

A relationship between working memory and mathematical performance has long been proposed (Geary, 2007; Hecht, 2002; Swanson, 2006; Swanson & Sachse-Lee, 2001). For example, in a study of 24 children with MLD, Swanson and Sachse-Lee (2001) found that difficulties in solving mathematical word problems were associated with working memory deficits. They propose that one of the main roles of working memory is to retrieve information from long-term memory, and their finding that the relationship between working memory and problem solving was mediated by deficits in accessing knowledge related to algorithms (for example, identifying the number sentence (e.g. 15 - 5 = ?) needed to solve a mathematical word-problem) supports this view.

In the current study the executive process of inhibiting was a significant predictor only of proportion/ratio, however this was no longer significant after children with severe NDI were excluded from analysis. The failure of inhibiting to predict mathematical achievement is surprising as Geary (2011) suggests that inhibiting irrelevant information is one of the main factors contributing to difficulties in retrieving information from long-term memory. He gives examples of two kinds of retrieval errors related to the inability to inhibit irrelevant information. The first is a table-related error, where a correct answer to a similar problem is given (e.g. the answer of 36 is given to the problem of 6 x 5) and the second is called a counting string error, where the retrieved answer follows one of the numbers in the question (e.g. 4 + 7 = 8).

On the other hand, other research has failed to find a relationship between inhibition and mathematical ability (Lee, Ng & Ng, 2009; van der Sluis, de Jong & van der Leij, 2007). For example, Lee, Ng and Ng (2009) failed to show a correlation between inhibition and algebraic tasks, and suggest that their task design may have limited the demand on children's ability to select and disregard unnecessary information. Furthermore, van der Sluis, de Jong and van der Leij (2007) failed to find an effect of inhibition on mathematical achievement in their sample of 172 9- to 12- year old children and suggest that in the general population individual differences in inhibition are small and/or very difficult to measure reliably. Similarly, in the current study of children born VPT, the failure of inhibition to predict poor mathematical achievement is likely due to the fact that the sample size was much reduced after excluding children with NDI. It is possible that this sample size (n = 42 – 50) was too small to allow an effect to be detected. A small sample size (i.e. n = 61 – 72) is also potentially the reason that the current study, in contrast to previous research, failed to show a predictive relationship between mathematical achievement and the BRIEF subscales of shifting attention, planning and monitoring.

Implications for Practice

It would be beneficial to equip teachers with knowledge about the relationship between potential vulnerabilities in mathematics and executive function, the risk of this for children born VPT, and with remediation knowledge and skills. For example, teachers should regularly screen students for mathematical difficulties, monitor the progress of these students and reteach specific skills when necessary. Remediation should focus on key maths topics and do the basics well, rather than covering many topics only briefly. Explicit teaching should include the teacher demonstrating and modelling proficient problem solving, giving guided practice with scaffolding, giving immediate feedback and correction, using concrete representations such as number lines and Cuisinaire rods and including plenty of praise and encouragement for effort and achievement.

As well as ensuring early identification and intervention for children with MLD, it is important to understand how to best provide remediation. The key to this is to understand why the child is performing poorly in mathematics. This study suggests that working memory deficits could be the underlying factor for the MLD observed in this group of children born VPT. The fact that poor working memory at age 6 years predicts mathematical learning difficulties at age 9 years provides some support for causality. Although there are few established evidence-based practices for improving working memory, two approaches – classroom-based support and working memory training - seem to be beneficial (Gathercole & Alloway, 2008). Classroom-based support is based on a combination of principles of cognitive theory and classroom practice and aims to structure learning activities in such a way so as to avoid overloading working memory. Teachers are trained to recognise and monitor task failures due to overloading the child's working memory, evaluate and reduce working memory loads where necessary, re-present information to the child, encourage the use of memory aids (such as wall posters, counters, and number lines), and develop the child's strategies to support memory (including asking for help, rehearsal, and note-taking). An alternative approach involves direct training of working memory skills through use of a computerised training programme, which provides activities that tax working memory. In one such programme, children worked on the computer for 35 minutes each day, for 20 days over a five- to seven- week period. Evaluations of this programme have found that it was successful in improving working memory in children with poor working memory (Holmes, Gathercole, & Dunning, 2009). Therefore, remediation that improves working memory, in conjunction with explicit instruction in mathematical concepts may be more effective than mathematics instruction alone.

Strengths and Limitations of the Current Study

Strengths of the present study include the use of standardised measures with good validity and reliability, ecologically valid measures, and the use of multiple report sources and measures to create a detailed description of each child's functioning. Using multiple measures has found areas of specific deficit that have not previously been shown in research using only a single measure of mathematical achievement. The use of a demographically representative full term comparison group is another strength, as is the particularly high retention rates of participants from the CCDRG sample. This decreases sample bias, meaning the participants in this study are representative of the range of children born VPT.

This study is not without its limitations, however, and findings must be interpreted in light of these. Several practical problems were encountered with the numeracy project assessment. For example, some data had to be retrospectively collected due to this measure not initially being included in the teacher questionnaire. Further contributing to the missing data were the facts that the numeracy project is only used in New Zealand schools (so no data was available from participants who were currently living out of New Zealand) and even in New Zealand, it is not used at every school. Furthermore, the numeracy project has seven subtests that can be administered at different times. As there is no standard time for these assessments to be administered, there was no guarantee that there would be complete data for each participant. The small sample size of children with available numeracy project data may have contributed to a reduction of statistical power in these analyses. It is possible an effect was there but there were not enough cases to provide the necessary power.

In the case of the teacher-rating scale, the Likert-type assessment measures used provide opportunity for teachers to interpret and rate children's performance based on their own biases. It is possible that teachers knew whether the child in question had been born VPT or not and that this may have affected their rating of the child's performance. Although teachers were not advised of the children's birth status, many may have had prior knowledge via discussion with parents. In order to gain less biased information in future it would be desirable for teachers to be blind as to birth status. However these limitations are mitigated against by the concurrent use of multiple measures and standardised assessment tools, on which children's scores were correlated with teacher ratings.

Another limitation is related to information that was not collected and/or included in analysis. There may be other factors that contribute to poor mathematical performance, including health, number of days absent from school and from maths in particular (e.g. in remedial reading instead) and behaviour issues. Prior research has shown that children born VPT are more likely to have more health problems than FT children. For example, Petrou et al (2001) found that even among children without severe NDI, children born VPT used hospital and GP services five times more frequently than FT children, even at the age of 8 – 9 years. If these problems resulted in a greater number of school absences then perhaps the tendency for children born VPT to have lower mathematical achievement than FT children could be due to these children having less mathematics instruction and practice than children born FT. Furthermore, in their meta-analysis, Bhutta et al (2002) found that children born VPT are two and a half times more likely than FT children to have attentional deficit/hyperactivity disorder (ADHD). Children with ADHD have poor academic outcomes including poor mathematics achievement (Loe & Feldman, 2007; Lucangeli & Cabrele, 2006).

Conversely, there may be factors that have contributed to improved performance among children born VPT, such as whether children had already participated in some kind of maths remediation. It is possible that some study children have already participated in intervention programmes that may have assisted their cognitive and/or academic functioning, therefore the full extent of the difficulties encountered may not be observed to their full degree.

Future Directions

In order to overcome these limitations, further research should aim to minimise missing data. One solution would be to administer an alternative measure in the university clinic. Ideally the measure would be one with a degree of cognitive profiling. However one difficulty is that these tests have a long administration time. If the numeracy project assessment is used, it would be best to collect end of year data for children. Once national standards are established, these could provide an alternative school-based measure.

Future longitudinal studies could control for possible effects of previous maths remediation. It would be beneficial to compare the mathematic achievement of children born VPT who have participated in remediation with those who have not, and this could help identify which remediation programmes, if any, are effective. Future work could also separate out children born extremely preterm in order to investigate a probable gradient effect. This would inform parents of preterm children what range of outcomes to expect if their child was born, for example, before 28 weeks.

Results of the current study revealed significant between group differences for the addition/subtraction and multiplication/division subtests of the numeracy project. It is interesting to note that these subtests comprise two of the three ‘strategy based’ components of the numeracy project, with the third being proportion/ratio. It is possible that proportion/ratio failed to reach significance because of a floor effect. The mean score of each group was relatively close, and this was the subtest with the lowest scores for both gestation groups, indicating that at age 9-years, proportion/ratio is a challenging skill for all children. Future follow-up assessment of the current study sample is needed in order to investigate whether this trend remains constant over time, or whether as children progress through the school years, a gap emerges between the groups. If a significant between group difference develops for the proportion/ratio subtest as well as addition/subtraction and multiplication/division, but not for any of the knowledge-based subtests, this would add weight to the proposal that children born VPT have a procedural deficit subtype of mathematical learning disability.

Finally, it is important that research goes beyond merely describing the difficulties likely to be encountered by children born VPT. Future research should be concerned with understanding underlying mechanisms contributing to difficulties in mathematics, with the view of developing effective interventions. Existing, as well as new interventions should be evaluated so as to inform schools of evidence-based interventions that will be most likely to improve the mathematic and academic achievement, and thus provide children born VPT with the best chance of achieving their true potential and living a fulfilling life.

Conclusion

Results from the current study are consistent with existing literature that has identified that children born VPT are likely to experience difficulties in mathematics. The current study has shown children born VPT score significantly lower than FT children on clinic- and school- based measures, and have higher rates of mathematical learning disabilities. These results remain after controlling for severe neurodevelopmental impairment, providing support for a specific maths learning disability, rather than mathematics underachievement being due to low IQ. On curriculum-based measures, children born VPT demonstrate difficulties in strategy-, but not knowledge-based subtests suggesting a procedural deficit subtype of learning disability. Geary has proposed that this is due to working memory deficits, and the current study adds support for this theory by demonstrating that mathematical learning disabilities at age 9 years is predicted by working memory deficits at age 6 years. This finding contributes to the literature, as it is the first study to show a longitudinal relationship between mathematical disability and working memory in the preterm population.

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APPENDIX 1

TEACHER QUESTIONNAIRE BOOKLET

TEACHER QUESTIONNAIRE

9 YEARS

CODE NUMBER:

TODAY'S DATE:

D	**D**	**M**	**M**	**Y**	**Y**

INSTRUCTIONS

This booklet contains a number of statements that describe children's play and social development. These statements cover a wide age range (5-12 years), so you may find that some seem a little inappropriate for your pupil. However, it would be very helpful if you could answer ALL of the questions as best you can even if you feel a little uncertain of your answer or the question seems a little daft.

Most questions involve ticking or circling your answer to each question. If you feel that an answer you give does not reflect your experiences adequately, please feel free to write additional comments in the spaces provided.

SECTION A. ACADEMIC ABILITY

A1: Essential Learning Areas

Overall, how would you rate this child's progress in the following academic areas in comparison with other children of the same age?

	More than 1-year delayed	Below average	Average	Above average	More than 1-year ahead
Mathematics	1	2	3	4	5
English Language Spoken	1	2	3	4	5
English Language Written	1	2	3	4	5
Art	1	2	3	4	5
Physical Education	1	2	3	4	5
Health	1	2	3	4	5
Technology	1	2	3	4	5

A.2 In your view, does this child have any learning problems in one or more of the above Essential Learning Areas?

Please specify:________________________________

A lot	1
Some	2
None	3

A3: Essential Learning Skills

Overall, how would you rate this child's progress in the following skill areas in comparison with other children of the same age?

	More than 1-year delayed	Below average	Average	Above average	More than 1-year ahead
Communication skills	1	2	3	4	5
Numeracy skills	1	2	3	4	5
Information skills	1	2	3	4	5
Problem-solving skills	1	2	3	4	5
Self-management and competitive skills	1	2	3	4	5
Social and co-operative skills	1	2	3	4	5
Physical skills	1	2	3	4	5
Work and Study skills	1	2	3	4	5

A.4 In your view, does this child have any learning difficulties in one or more of the above Essential Learning Skills?

Please specify:___________________________________

A lot	1
Some	2
None	3

A.5 Please indicate whether the following behaviours are characteristic of the child by circling either:
1 = Never;
2, 3, or 4 = Sometimes (base your judgement on how frequently the behaviour occurs)
5 = Frequently

	Never	Sometimes	Frequently
Makes appropriate transitions between different activities	1	2 3 4	5
Completes school work without being reminded	1	2 3 4	5
Listens to and carries out directions from teachers	1	2 3 4	5
Asks appropriately for clarification of instructions	1	2 3 4	5
Completes school assignments or other tasks independently	1	2 3 4	5
Completes school assignments on time	1	2 3 4	5
Asks for help in an appropriate manner	1	2 3 4	5
Produces work of acceptable quality for his/her level	1	2 3 4	5

SECTION B. MATH

B.1. MATH STRATEGIES

a) When presented with a math word problem, is this pupil able to:

	Unable to Do	Developing Ability	Mostly Able	Able	Very Able
Sort out important information from extraneous information that is not essential for solving the problem	1	2	3	4	5
Implement a plan for solving the problem	1	2	3	4	5
Work through multiple steps in more advanced word problems	1	2	3	4	5
Use the correct calculations to solve problems	1	2	3	4	5

	None	Below Average for their Age	Average	Above Average for their Age	Advanced
b) What level of understanding does this pupil have about the relationships between numbers (e.g., addition and subtraction; multiplication and division, fractions and decimals)	1	2	3	4	5

B.2. MATH FACTS

Please estimate how well this pupil is able to…	Unable to Do	Below Average Ability for their Age	Average Ability	Above Average Ability for their Age	Advanced Ability
Learn basic math rules (e.g., any number x 0 = 0)	1	2	3	4	5
Retrieve (remember) basic math rules (e.g., any number x 0 =0)	1	2	3	4	5
Recall the steps needed to solve word problems	1	2	3	4	5
Able to remember what specific symbols mean (e.g., +, x, ÷, ≥, ≤,-)	1	2	3	4	5

B.3. UNDERSTANDING NUMBERS

Please estimate this pupil's ability to…	Unable to Do	Below Average Ability	Average Ability	Above Average Ability	Advanced Ability
Correctly place numbers in columns when solving an equation	1	2	3	4	5
Tell which of two numbers is the largest	1	2	3	4	5
Correctly align numbers when copying problems from the chalkboard or text	1	2	3	4	5

B.4. MATH DIFFICULTIES

a) Does this pupil have difficulties with any of the following…

	Much Difficulty	Some Difficulty	No Difficulty
Identifying signs and their meanings (e.g., +, x, ÷, ≥, ≤,-)	1	2	3
Conceptualizing time and judging the passing of time	1	2	3
Differentiating between left and right	1	2	3
Distinguishing north, south, east, and west	1	2	3
Navigating a map	1	2	3
Estimating the measurement (size) of an object	1	2	3
Estimating the measurement of distance (e.g., whether something is 1metre away or 5 metres away)	1	2	3

b). Please estimate how well this pupil is able to…

	Below Average	Average	Above Average
Use “mental” counting strategies (rather than relying on ‘counting-on’ strategies such as using fingers)	1	2	3
Work with number sets (e.g., circling sets of shapes that add up to 5)	1	2	3

SECTION C: CHILD STRENGTHS AND DIFFICULTIES

C.1. For each of the following items, please circle the number that best describes your pupil’s behaviour in the last 6 months.

	Not True	Some-what True	Certainly True
Considerate of other people’s feelings	1	2	3
Restless, overactive, cannot stay still for long	1	2	3
Often complains of headaches, stomach-aches or sickness	1	2	3
Shares readily with other children (treats, toys, pencils, etc)	1	2	3

	Not True	Some-what True	Certainly True
Often has temper tantrums or hot tempers	1	2	3
Rather solitary, tends to play alone	1	2	3
Generally obedient, usually does what adults request	1	2	3
Many worries, often seems worried	1	2	3
Helpful if someone is hurt, upset or feeling ill	1	2	3
Constantly fidgeting or squirming	1	2	3
Has at least one good friend	1	2	3
Often fights with other children or bullies them	1	2	3
Often unhappy, down-hearted or tearful	1	2	3
Generally liked by other children	1	2	3
Easily distracted, concentration wanders	1	2	3
Nervous or clingy in new situations, easily loses confidence	1	2	3
Kind to younger children	1	2	3
Often argumentative with adults	1	2	3
Picked on or bullied by other children	1	2	3
Often volunteers to help others (parents, teachers, other children)	1	2	3
Thinks things out before acting	1	2	3
Can be spiteful to others	1	2	3
Gets on better with adults than with other children	1	2	3
Many fears, easily scared	1	2	3
Sees tasks through to the end, good attention span	1	2	3

C.2 Overall, do you think that this child has difficulties in one or more of the following areas: Emotions, concentration, behaviour or being able to get on with other people?

No	Yes-minor difficulties	Yes-definite difficulties	Yes-severe difficulties
0	1	2	3

If you have answered “Yes”, please answer the following questions about these difficulties: (**Otherwise skip to C.7**)

C.3 How long have these difficulties been present?

Less than a month	1-5 months	6-12 months	Over a year
0	1	2	3

C.4 Do the difficulties upset or distress the child?

Not at all	Only a little bit	Quite a lot	A great deal
0	1	2	3

C.5 Do the difficulties interfere with the child’s everyday life in the following areas?

PEER RELATIONSHIPS

Not at all	Only a little bit	Quite a lot	A great deal
0	1	2	3

CLASSROOM LEARNING

Not at all	Only a little bit	Quite a lot	A great deal
0	1	2	3

C.6 Do the difficulties put a burden on you or the class as a whole?

Not at all	Only a little bit	Quite a lot	A great deal
0	1	2	3

C.7 Below are a number of common problems children have in school. Please complete the following: Rate each item according to how much of a problem it has been in the last month. For each item, ask yourself, "How much of a problem has this been in the last month?", and circle the best answer for each one. If none, not at all, seldom, or very infrequently, you would circle 0. If very much true, or it occurs very often or frequently, you would circle 3. You would circle 1 or 2 for ratings in between. (Copyright 1997, Multi-Health Systems Inc)

	Not True (Never, Seldom)	Just a Little True (Occasionally)	Pretty Much True (Often, Quite a bit)	Very Much True (Very often, Very frequently)
Does not get along with opposite sex	0	1	2	3
Is uncooperative with other children	0	1	2	3
Inattentive, easily distracted	0	1	2	3
Defiant	0	1	2	3
Is inconsiderate of other children	0	1	2	3
Restless in the "squirmy" sense	0	1	2	3
Forgets things he/she has already learned	0	1	2	3
Disturbs other children	0	1	2	3
Actively defies or refuses to comply with adults' requests	0	1	2	3
Is always "on the go" or acts as if driven by a motor	0	1	2	3
Poor in spelling	0	1	2	3
Cannot remain still	0	1	2	3
Spiteful or vindictive	0	1	2	3
Leaves seat in classroom or in other situations in which remaining seated is expected	0	1	2	3
Fidgets with hands or feet or squirms in seat	0	1	2	3
Not reading up to par	0	1	2	3
Short attention span	0	1	2	3
Argues with adults	0	1	2	3

	Not True (Never, Seldom)	Just a Little True (Occasionally)	Pretty Much True (Often, Quite a bit)	Very Much True (Very often, Very Frequent)
Is unhelpful and unsupportive of other children	0	1	2	3
Only pays attention to things he/she is really interested in	0	1	2	3
Has difficulty waiting his/her turn	0	1	2	3
Lacks interest in schoolwork	0	1	2	3
Distractibility or attention span a problem	0	1	2	3
Temper outbursts; explosive, unpredictable behaviour	0	1	2	3
Runs about or climbs excessively in situations where it is inappropriate	0	1	2	3
Is a not a “good sport” in games or other activities	0	1	2	3
Poor in arithmetic	0	1	2	3
Does not get along with the same sex	0	1	2	3
Interrupts or intrudes on others (e.g., butts into others’ conversations or games)	0	1	2	3
Has difficulty playing or engaging in leisure activities quietly	0	1	2	3
Fails to finish things he/she starts	0	1	2	3
Does not follow through on instructions and fails to finish schoolwork (not due to oppositional behaviour or failure to understand instructions)	0	1	2	3
Excitable, impulsive	0	1	2	3
Isolates self from other children	0	1	2	3
Restless, always up and on the go	0	1	2	3
Not much liked by other children	0	1	2	3
Appears to be unaccepted by group	0	1	2	3

C.8 Please complete the following by circling 0 if the statement is not true of this child, 1 if it is quite or sometimes true, and 2 if it is very often true of this child.

	Not True	Some-what True	Often true
Lacks an awareness of other people's feelings	0	1	2
Does not realise when others are upset or angry	0	1	2
Is oblivious to the effect of his/her behaviour on other members of the class	0	1	2
Behaviour often disrupts normal class routine	0	1	2
Very demanding of people's time	0	1	2
Difficult to reason with when upset	0	1	2
Does not seem to understand social skills (e.g. interrupts conversation)	0	1	2
Does not pick up on body language	0	1	2
Unaware of acceptable social behaviour	0	1	2
Unknowingly offends people with behaviour	0	1	2
Does not respond to commands	0	1	2
Has difficulty following commands unless they are carefully worded	0	1	2

C.9 How popular is this child with his/her classmates?

Very popular	1
Well liked	2
Liked	3
Tolerated	4
Unpopular	5
Very unpopular	6
Isolated	7

SECTION D: SOCIAL AND COGNITIVE BEHAVIOUR

Following is a list of statements that describe young children. Please indicate if your child has had problems with these behaviours over the past 6 months.

	Never	Some-times	Often
Over-reacts to small problems	1	2	3
When given two things to do, remembers only the first or last	1	2	3
Is not a self-starter	1	2	3
Cannot get a disappointment, scolding or insult off his/her mind	1	2	3
Resists or has trouble accepting a different way to solve a problem with schoolwork, friends, chores etc	1	2	3
Becomes upset with new situations	1	2	3
Has explosive, angry outbursts	1	2	3
Has a short attention span	1	2	3
Needs to be told “no” or “stop that”	1	2	3
Needs to be told to begin a task even when willing to do it	1	2	3
Loses lunch money, permission slips, homework etc.	1	2	3
Does not bring homework, assignment sheets, materials etc.	1	2	3
Acts upset by a change in plans	1	2	3
Is disturbed by a change of teacher or class	1	2	3

	Never	Some-times	Often
Does not check work for mistakes	1	2	3
Cannot find clothes, glasses, toys, books, pencils etc.	1	2	3
Has good ideas but can't get them on paper	1	2	3
Has trouble concentrating on chores, homework etc.	1	2	3
Does not show creativity in problem solving	1	2	3
Backpack is disorganised	1	2	3
Is easily distracted by noises, activity, sights etc.	1	2	3
Makes careless mistakes	1	2	3
Forgets to hand in homework, even when completed	1	2	3
Resists change of routine, foods, places etc.	1	2	3
Has trouble with chores or tasks that have more than one step	1	2	3
Has outbursts for little reason	1	2	3
Mood changes frequently	1	2	3
Needs help from an adult to stay on task	1	2	3
Gets caught up in details and misses the big picture	1	2	3
Has trouble getting used to new situations (classes, groups, friends)	1	2	3
Forgets what he/she was doing	1	2	3
When sent to get something, forgets what he/she was supposed to get	1	2	3
Is unaware of how his/her behaviour affects or bothers others	1	2	3

	Never	Some-times	Often
Has trouble coming up with different ways of solving a problem	1	2	3
Has good ideas but does not get the job done (lacks follow-through)	1	2	3
Leaves work incomplete	1	2	3
Becomes overwhelmed by large assignments	1	2	3
Does not think before doing	1	2	3
Has trouble finishing tasks	1	2	3
Thinks too much about the same topic	1	2	3
Interrupts others	1	2	3
Is impulsive	1	2	3
Does not notice when his/her behaviour causes negative reactions	1	2	3
Gets out of seat at the wrong times	1	2	3
Is unaware of own behaviour when in a group	1	2	3
Gets out of control more than friends	1	2	3
Reacts more strongly to situations than other children	1	2	3
Starts assignments or chores at the last minute	1	2	3
Has trouble getting started on homework or chores	1	2	3
Mood is easily influenced by the situation	1	2	3
Does not plan ahead for school assignments	1	2	3
Gets stuck on one topic or activity	1	2	3

	Never	Some-times	Often
Has poor understanding of his/her own strengths and weaknesses	1	2	3
Talks or plays too loudly	1	2	3
Written work is poorly organised	1	2	3
Acts too wild or out of control	1	2	3
Has trouble putting the breaks on his/her actions	1	2	3
Gets in trouble if not supervised by an adult	1	2	3
Has trouble remembering something, even for a few minutes	1	2	3
Work is sloppy	1	2	3
After having a problem, will stay disappointed for a long time	1	2	3
Does not take initiative	1	2	3
Angry or tearful outbursts are intense, but end suddenly	1	2	3
Does not realise that certain actions bother others	1	2	3
Small events trigger big reactions	1	2	3
Cannot find things in room or school desk (pencil case etc)	1	2	3
Leaves a trail of belongings wherever he/she goes	1	2	3
Does not think of consequences before acting	1	2	3
Has trouble thinking of a different way to solve a problem when stuck	1	2	3
Leaves messes that others have to clean up	1	2	3
Becomes upset too easily	1	2	3
Has a messy desk	1	2	3

	Never	Some-times	Often
Has trouble waiting for turn	1	2	3
Does not connect doing work with grades	1	2	3
Tests poorly even when he/she knows the correct answers	1	2	3
Does not finish long-term projects	1	2	3
Has poor handwriting	1	2	3
Has to be closely supervised	1	2	3
Has trouble moving from one activity to another	1	2	3
Is fidgety	1	2	3
Cannot stay on the same topic when talking	1	2	3
Blurts things out	1	2	3
Says the same things over and over	1	2	3
Talks at the wrong time	1	2	3
Does not come prepared for class	1	2	3

SECTION E: ATTENDANCE

E.1: Is this child receiving any additional support services at school? (either individually or in a small group)	Yes	No
Reading Recovery or similar special reading or literacy programme	1	2
Perceptual Motor programme	1	2
Teacher aide	1	2
Behaviour Management Programme	1	2
Occupational Therapy/Physio	1	2
Social Skills Programme	1	2
Speech and Language Therapy	1	2
Any other support. Please specify (i.e., language support, ESOL,)……………………………………………..	1	2

E.2 How would you rate this child's physical stamina in comparison to other children within their age group (i.e. do the become tired, weak or irritable more easily)

Much lower than peers	1
Quite low	2
About the same as others	3
Higher than others	4

E.4 Do you have any concerns about this child's achievement and behaviour?

____

____

____

SECTION F. CHILD’S GENERAL HEALTH

	Yes	No
F.1. Is this child currently on any form of prescribed medication at school?	1	2

If yes, please give details ____

F.2. Does this child wear glasses or lenses to correct their vision at school?

No	0
Glasses	1
Lenses/Contacts	2
Other (please specify): ………………………………………..	3

F.3

a) Does this child wear a hearing aid at school?

b) How well can s/he hear at school?

No hearing problem	0
Has some hearing loss, but does NOT wear a hearing aid	1
Hears well or with little difficulty WITH a hearing aid	2
Has severe hearing difficulty even with a hearing aid	3

SECTION G: SCHOOL RECORD DATA

Child's Year Level ___________

Circle Tests Used	**Yes**	**No**	
STAR Reading Test	0	1	If yes, please fill in results on page 18
Neale Analysis of Reading Ability	0	1	If yes, please fill in results on page 19
Burt Word Reading Test	0	1	If yes, please fill in results on page 20
PAT: Reading	0	1	If yes, please fill in results on page 20
PAT: Mathematics	0	1	If yes, please fill in results on page 20
KeyMath	0	1	If yes, please fill in results on page 21
Numeracy Project	0	1	If yes, please fill in results on page 22
Other tests used (please specify)			Space is provided for details and results of other tests used on page 22

Please fill in the sections that correspond to each of the tests used.

G.1 STAR Reading Test

Date Tested: _______________

Age at Testing: _____________

Subtests Administered	Raw Score
1. Word Recognition	
2. Sentence Comprehension	
3. Paragraph Comprehension	
4. Vocab Range	
Total Score:	
Stanine Score:	

G.2 Neale Analysis of Reading Ability

Date Tested: _______________

Age at Testing: _____________

Circle the tests Used

	Yes	No
Form 1	0	1
Form 2	0	1
Diagnostic Tutor Form A	0	1
Diagnostic Tutor Form B	0	1

Standardized Score Summary

	Raw Score	Percentile Rank	Stanine	Reading Age
Accuracy				
Comprehension				
Rate				

Error Count

	% of Total Count
Total Mispronunciations	
Total Substitution	
Total Refusals	
Total Additions	
Total Omissions	
Total Reversals	
Total Errors	

G.3 Burt Word Reading Test

Date Tested: _______________

Age at Testing: _____________

Number correct	
Equivalent Age Band	
Norms Used: (circle one):	Boys Girls Boys and Girls

G.4 PAT: Reading

Date Tested: _______________

Age at Testing: _____________

	Level Score	Percentile Score	Stanine
Reading Comprehension			
Reading Vocabulary			

G.5 PAT: Mathematics

Date Tested: _______________

Age at Testing: _____________

Level	Level Score	Percentile Score	Stanine

G.6 KeyMath

Date Tested: ______________

Age at Testing: ____________

SubTest	SubTest Score
Numeration	
Rational Numbers	
Geometry	
Addition	
Subtraction	
Multiplication	
Division	
Mental Computation	
Measurement	
Time and Money	
Estimation	
Interpreting Data	
Problem Solving	

Area	Area Composite Score
Basic Concepts	
Operations	
Applications	

KeyMath Test Score:	

G.7 Numeracy Project

Child's Year Level ___________

Date Tested (day/month/year): ________________

Age at Testing: ______________

Nb: If this assessment was not used by your school, please code the spaces as N/A.

Operational Strategy	**Stage**
Addition/Subtraction	
Multiplication/Division	
Proportions/Ratios	
Knowledge Domain	
Number identification	
Number sequence and order	
Grouping and place value	
Basic facts	

G.7 Other Tests Used

Please provide details and scores

ADDITIONAL COMMENTS

If you have any further comments that you would like to add, please feel free to use the space below:

THANK YOU FOR YOUR HELP!

APPENDIX 2

NUMERACY PROJECT DIAGNOSTIC INTERVIEW

Operational Strategy Windows
Addition and Subtraction

The answers to these tasks determine which form of Numeracy Project Assessment to use. Keep a note of the student's response to each question.

Task (1): Count eight objects.

Actions: Provide the student with access to a pile of counters of the same colour.

Say: Please get 8 counters for me.

Decision: If the student did not count eight items, rate him/her as stage 0 on operational strategies. Proceed to form A. Otherwise proceed to task (2).

Task (2): Work out 4 + 3 on materials.

Actions: Place four counters in the student's hand. Place three counters in the student's other hand. Ask the student to close their hands. (Open later if necessary).

Say: Please hold out your hands for me. Here are 4 counters. Here are another 3 counters. How many counters have you got altogether?

Decision: If the student was unable to solve 4 + 3 correctly, rate them at stage 1. Proceed to form A. If the student solved 4 + 3 by counting the materials, rate her/him at stage 2. Proceed to form A. Otherwise proceed to task (3).

Task (3): Find 8 + 5 = □.

Actions: Place 8 counters of one colour under a card and 5 counters of another colour under another card. Reveal the collections to the student then cover them, one at a time. Show the problem card to the student.

Say: There are 8 counters under this card and 5 counters under this card. How many counters are there altogether?

Decision: If the student solved task (2) by imaging but did not solve task (3) by counting on, rate her/him at stage 3. Proceed to form A. Otherwise proceed to task (4). If the student solved task (3) by counting on, still give her/him task (4) as this may provoke part-whole thinking.

Task (4): Find 9 + 8 = □.

Actions: Place 9 counters of one colour under a card and 8 counters of another colour under another card. Reveal the collections to the student then cover them, one at a time. Show the problem card to the student.

Say: There are 9 counters under this card and 8 counters under this card. How many counters are there altogether?

Decision: If the student solved both tasks (3) and (4) by counting on, rate her/him at stage 4. Proceed to form B. For students who used any part-whole strategy for either or both tasks (3) and (4), continue to task (5).

Task (5): Find 37 – 9.

Actions: Show the card with the lolly problem on it to the student.

Say: You have 37 lollies, and you eat 9 of them. How many lollies have you got left?

Decision: If the student used any part-whole strategies on tasks (3) and (4) but counted back to solve task (5), rate her/him at stage 5. Proceed to form B. If the student used a part-whole strategy on task (5), proceed to task (6).

Task (6): Find 53 – 26.

Actions: Show the card with the bus problem written on it.

Say: There are 53 people on the bus. 26 people get off. How many people are left on the bus?

Decision: If the student imagined using a standard written method, read the notes at the end of task (8). If the student failed to solve this problem correctly, rate her/him at stage 5 and proceed to form B.

Task (7): Find 394 + 79.

Actions: Show the card with the stamp problem written on it.

Say: Sandra has 394 stamps. She gets another 79 stamps from her brother. How many stamps does she have then?

Decision: If the student gets both of tasks (6) and (7) correct using part-whole strategies, proceed to task 8. Otherwise rate the student at stage 5 and proceed to form B.

Task (8): Find 5.3 – 2.89 metres.

Actions: Show the card with the sewing problem written on it.

Say: Marija has a 5.3 metre length of fabric. She uses 2.89 metres of it to make a tracksuit. How much fabric has she got left?

Decision: Regardless of the student's answer, proceed to task 9.

Task (9): Find 2 – (¾ + 7/8) pizza.

Actions: Show the card with the pizza problem written on it.

Say: Harry and Sally buy two pizzas. Harry eats ¾ of a pizza while his friend Sally eats 7/8 of a pizza. How much pizza is left over?

Decision: If the student gets both Tasks (8) and (9) correct using part-whole strategies, rate her/him at stage 7 for addition and subtraction. Otherwise rate the student at stage 6. Proceed to form C.

Note about Standard Written Forms

If the student's method on any problem was to perform standard written form in their head, then no conclusions should be drawn about their strategy stage. Further questioning is needed to establish their strategy stage. For example:

- "Can you do that in a different way?"
- "Explain how the written method works." Look for evidence of part-whole reasoning; for example, for 53 – 26, the student clearly understands that 53 is the same as four tens and 13 ones.

Stage & Behavioural Indicator	Use form:
0 Emergent The student has no reliable strategy for counting an unstructured collection of items.	A
1 One-to-one Counting The student has a reliable strategy for counting an unstructured collection of items.	A
2 Counting from One on Materials The student's most advanced strategy is counting from one on materials to solve addition problems.	A
3 Counting from One by Imaging The student's most advanced strategy is counting from one without the use of materials to solve addition problems.	A
4 Advanced Counting The student's most advanced strategy is counting on or counting back to solve addition or subtraction tasks.	B
5 Early Additive Part-Whole The student uses any part-whole strategy to solve addition or subtraction problems mentally by reasoning the answer from basic facts and/or place value knowledge.	B
6 Advanced Additive–Early Multiplicative Part-Whole The student is able to use at least two different mental strategies to solve addition or subtraction problems with multi-digit numbers.	C
7 Advanced Multiplicative–Early Proportional Part-Whole The student is able to use at least two different mental strategies to solve addition or subtraction problems with decimals and fractions with related denominators.	C

Numeracy Project Assessment Form A

Transfer the notes from the Strategy Windows tasks (pages 4 and 5) to the addition and subtraction stage boxes on the Individual Assessment Sheet.

Knowledge Questions
Forwards Number Word Sequence (FNWS)

Things the interviewer says are in bold. Comments for the interviewer appear in plain type.

(1) **Start counting from 1. I will tell you when to stop.** Stop at 32.
What's the next number after...? If the student does not understand the meaning of the question, say: **The next number after 2 is 3. So if I say 2, you say 3.**
What is the next number after …? (2) **5** (3) **9**

For questions (4) to (7), listen carefully for confusion between "teen" and "ty". If the student has this confusion, they are assessed at no higher than stage 2.

What's the next number after ...?
(4) **13** (5) **19** (6) **12** (7) **15**

If the student confuses "teen" and "ty" in questions (4) to (7), it is still worthwhile to ask questions (8) to (11) to see if the confusion is only with the "teen" numbers.

What's the next number after ...?
(8) **29** (9) **46** (10) **69** (11) **80** (12) **139** (13) **899**

Stage & Behavioural Indicator

0 Emergent FNWS The student cannot produce the FNWS from 1 to 10.
1 Initial FNWS up to 10 The student can produce the FNWS from 1 to 10 but cannot produce the number just after a given number in the range 1 to 10.
2 FNWS up to 10 The student can produce the number just after a given number in the range 1 to 10 without dropping back.
3 FNWS up to 20 The student can produce the number just after a given number in the range 1 to 20 without dropping back.
4 FNWS up to 100 The student can produce the number just after a given number in the range 1 to 100 without dropping back.
5 FNWS up to 1 000 The student can produce the number just after a given number in the range 1 to 1 000 without dropping back.

For the forwards and backwards number word sequences, dropping back means that the student says or mentally counts several numbers up to the given number. He/she then says the number before or after that number. For example, the student finds the number after five by saying one, two, three, four, five, six. A student finds the number before 14 by saying 10, 11, 12, 13, 14, then says 13.

Backwards Number Word Sequence (BNWS)

(14) **Count backwards from 10. I will tell you when to stop.** Stop at 0 or 1.

(15) **Count backwards from 24. I will tell you when to stop.** Stop at 11.

What number comes before ...?
If the student does not understand the meaning of the question, say: **The number that comes before 2 is 1. So if I say 2, you say 1.**
What number comes before …?
(16) **3** (17) **9** (18) **5** (19) **8**

For questions (20) to (23), listen carefully for confusion between “teen and “ty”. If the student has this confusion, they are assessed at no higher than stage 2.

What number comes before ...?

(20) **16** (21) **20** (22) **17** (23) **11** (24) **13**

If the student confuses “teen” and “ty” in questions (20) to (24), it is still worthwhile to ask questions (25) to (26) to see if the confusion is only with the teen numbers.

What number comes before ...?

(25) **31** (26) **47** (27) **70** (28) **236** (29) **600**

Stage & Behavioural Indicator

0 Emergent BNWS The student cannot produce the BNWS from 10 to 0.
1 Initial BNWS back from 10 The student can produce the BNWS from 10 to 0 but cannot produce the number just before a given number in the range 0 to 10.
2 BNWS back from 10 The student can produce the number just before a given number in the range 0 to 10 without dropping back.
3 BNWS back from 20 The student can produce the BNWS from 20 to 0, and the number just before a given number in the range 0 to 20 without dropping back.
4 BNWS back from 100 The student can produce the BNWS from 100 to 0, and the number just before a given number in the range 0 to 100 without dropping back.
5 BNWS back from 1 000 The student can produce the BNWS from 1 000 to 0, and the number just before a given number in the range 0 to 1 000 without dropping back.

Numeral Identification

What is this number? Show cards with the number written on them.

(30) **3**	(31) **9**	(32) **5**	(33) **1**	(34) **8**	
(35) **6**	(36) **0**	(37) **4**	(38) **2**	(39) **7**	(40) **10**

For questions (41) to (45), listen carefully for confusion between "teen" and "ty". If the student has this confusion, they are assessed at stage 1.

What is this number?

(41) **13** (42) **19** (43) **11** (44) **16** (45) **12**

If the student confuses "teen" and "ty" in questions (41) to (45), it is still worthwhile to ask questions (46) to (49) to see if the confusion is only with the "teen" numbers.

What is this number?

(46) **66** (47) **43** (48) **80** (49) **38** (50) **137** (51) **702**

Stage & Behavioural Indicator

0 Emergent Numeral Identification The student cannot identify most of the numerals in the range 0 to 10.
1 Numerals to 10 The student can identify the numerals in the range 0 to 10.
2 Numerals to 20 The student can identify the numerals in the range 0 to 20.
3 Numerals to 100 The student can identify one- and two-digit numbers.
4 Numerals to 1 000 The student can identify two- and three-digit numbers.

Place Value

(52) Place a four-strip horizontally on the table. Now place a ten-strip beneath the four-strip.
Say: **Here are four dots. Here are ten more dots. How many dots are there now?**
Continue adding ten-strips to show 24, 34, 44, 54, 64, 74, asking the student to name the total number of dots each time.

If the student cannot count the total number of dots for four and ten, rate him/her at stage 0–1. If the student counts all the dots to find totals of 14 and 24, rate him/her at stage 2. If the student counts in fives and ones to find totals of 14 and 24, rate him/her at stage 3. For students who add ten each time to their previous answer when a new strip is added, 14, 24, 34, 44, ..., tentatively rate them at stage 4. You may wish to further assess their place value understanding using questions 27 and 28 of Form B.

Stage & Behavioural Indicator

0–1 Emergent The student cannot count the number of objects in combined collections.
2 One as a Unit The student finds the total number of objects in collections by counting all of the objects by ones. He/she does not use ten as a counting unit.
3 Five as a Counting Unit The student uses five as a counting unit, for example, 5, 10, 11, 12, 13, 14.
4 Ten as a Counting Unit The student uses ten as a counting unit, for example, 10, 20, 30, 40, 41, 42, 43, 44.

Basic Facts

For questions (53) to (59), show the equation from the test booklet and read it out aloud. Instant recall of the answers is required rather than counting methods.

Tell me the answer to ...

(53) **2 + 3**	(54) **5 + 4**	(55) **6 and what makes 10?**	
(56) **6 + 6**	(57) **9 + 9**	(58) **10 + 4**	(59) **7 + 10**

Stage & Behavioural Indicator

0–1 Emergent The student is unable to recall instantly facts to five, for example, 2 + 3.
2 Addition Facts to Five The student instantly recalls facts to five, for example, 2 + 3.
3 Addition Facts to Ten The student instantly recalls facts to ten, for example, 5 + 4, 6 + □ = 10.
4 Addition Facts with Tens and Doubles The student recalls the doubles to 20, and teen facts, for example, 14 = 10 + 4.

Based on: Wright, R. J., Martland, J., & Stafford, A. (2000). Early Numeracy: Assessment for Teaching and Intervention. London: Paul Chapman Publications/Sage. Acknowledgement is made that some of the ideas for questions were originally sourced from the New South Wales's Count Me In Too Professional Development Package (1999). Department of Education and Training Publishers. New South Wales, Australia.

Numeracy Project Assessment Form B

Transfer the notes from the Strategy Windows tasks (pages 4 and 5) to the addition and subtraction stage boxes on the Individual Assessment Sheet.

Operational Strategy Questions
Multiplication and Division

Things the interviewer says are in bold. Comments for the interviewer appear in plain type.

(1) **Here is a forest of trees. There are 5 trees in each row, and there are 8 rows.** Use horizontal and vertical sweeps with the index finger. Mask all but one horizontal and one vertical edge of the array. **How many trees are there in the forest altogether?** If the student is unable to give an answer, uncover the rest of the sheet. **If I planted 15 more trees, how many rows of 5 would I have then altogether?**

If the students solves question (1) using one-to-one counting and/or skip-counting, omit questions (2) and (3). Rate him/her at stages 2–3 or 4, as appropriate. Stop the multiplication questions and proceed to the questions on proportions and ratios.

For questions (2) and (3), screen the answer then uncover it if the student responds correctly. If the student gives no response or an incorrect one, go to the proportions and ratios section.

(2) **What is 3 x 20?**
If 3 x 20 = 60, what does 3 x 18 equal?
Does the student derive 3 x 18 by 60 – 6 = 54?
(3) **What is 5 x 8? If 5 x 8 = 40, what does 5 x 16 equal ?**
Does the student derive 5 x 16 = 80 by doubling 40?
Rate the student according to the most advanced strategy he/she uses on questions (2) and (3). Note that the student can know how to derive multiplication facts from other known facts, that is, he/she could be at stage 6 but use counting on or back.

Stage & Behavioural Indicator
2–3 Counting from One The student solves multiplication problems by counting all of the objects.
4 Advanced Counting The student solves multiplication problems by skip-counting, where he/she has a known sequence or by using a combination of skip-counting and counting in ones, for example, 5, 10, 15, 20.
5 Early Additive Part-Whole The student solves multiplication problems by forming the factors where they have a known multiplication fact or by using repeated addition, for example, for 5 x 8: 5 + 5 = 10, 10 + 10 + 10 + 10 = 40
6 Advanced Additive–Early Multiplicative Part-Whole The student solves multiplication problems by deriving from known multiplication facts, for example, 3 x 20 = 60 so 3 x 18 = 60 – (3 x 2) = 54.

(4) Show the student the fraction circle sheet. **Which of these cakes has been cut into thirds?** If the student responds incorrectly, point to the thirds. **Here are 12 jelly beans to spread out evenly on top of the cake. You eat one-third of the cake. How many jelly beans do you get?** If the student cannot answer the question, allow them to manipulate the beans or counters to solve it. If the student needs to manipulate the materials to solve question (4), rate them at stage 1 or 2–4, as appropriate, and proceed to the knowledge questions.

(5) **What is ¾ of 28?** Does the student use a part-whole strategy based on addition and/or multiplication?

Stage & Behavioural Indicator

1 Unequal Sharing The student is unable to find a fraction of a number by sharing the objects into equal subsets.
2–4 Equal Sharing The student finds a fraction of a number by sharing the objects into equal subsets, physically or by imaging.
5 Early Additive Part–Whole The student finds a unit fraction of a number mentally, using trial and improvement with addition facts, for example, 1/3 of 12 as 4 + 4 + 4 = 12.
6 Advanced Additive–Early Multiplicative Part–Whole The student finds a fraction of a number mentally, using a combination of addition facts and multiplication, for example, ¾ of 28 as: ¼ of 20 = 5 so ¼ of 24 = 6 so ¼ of 28 = 7, 3 x 7 = 21; or of ½ 28 is 14, ½ of 14 is 7, 14 + 7 = 21.

Knowledge Questions
Forwards Number Word Sequence (FNWS)

Ask question (6) only if the student is at the advanced counting stage. For other students proceed to question (7).

(6) **Start counting from 10. I will tell you when to stop.** Stop at 32. If the student has problems counting up through the teens, rate him/her at stage 2 and proceed to the BNWS questions.

For each number I show you, read the number then tell me the number that comes just after it, the number that is one more. For example, if I show you 4, you say 5. Show the FNWS cards. Stop at the point at which the student encounters difficulty and proceed to the BNWS questions.

(7) 12	(8) 17	(9) 29	(10) 99	(11) 209
(12) 999	(13) 3 049	(14) 989 999		

For the forwards and backwards number word sequences, dropping back means that the student says or mentally counts several numbers up to the given number. He/she then says the number before or after that number. For example, the student finds the number after 25 by saying 21, 22, 23, 24, 25, 26. A student finds the number before 14 by saying 10, 11, 12, 13, 14, then says 13. Rate the student at the highest stage in which they get all relevant questions (7) to (14) correct.

Stage & Behavioural Indicator

2 FNWS up to 10 The student can read and give the number just after a given number in the range 1 to 10 without dropping back.
3 FNWS up to 20 The student can read and produce the number just after a given number in the range 1 to 20 without dropping back.
4 FNWS up to 100 The student can read and produce the number just after a given number in the range 1 to 100 without dropping back.
5 FNWS up to 1 000 The student can read and produce the number just after a given number in the range 1 to 1 000.
6 FNWS up to 1 000 000 The student can read and produce the number just after a given number in the range 1 to 1 000 000.

Backwards Number Word Sequence (BNWS)

Ask question (15) only if the student is at the advanced counting stage. For other students, proceed to question (16).

(15) **Start counting backwards from 23. I will tell you when to stop.** Stop at 10. If the student has problems counting back through the teens, rate him/her at stage 2 and proceed to the fractional numbers questions.

For each number I show you, read the number then tell me the number that comes just before it, that is, the number that is one less. For example, if I show you 4, you say 3.
Show the BNWS cards. Stop at the point the student encounters difficulty and proceed to the fractional number questions.

(16) 13 (17) 19 (18) 30 (19) 100 (20) 680
(21) 900 (22) 2 400 (23) 603 000

Rate the student at the highest stage in which they get all relevant questions (16) to (23) correct.

Stage & Behavioural Indicator

2 BNWS back from 10 The student can read and give the number just before a given number in the range 1 to 10 without dropping back.
3 BNWS back from 20 The student can read and produce the number just before a given number in the range 1 to 20 without dropping back.
4 BNWS back from 100 The student can read and produce the number just before a given number in the range 1 to 100 without dropping back.
5 BNWS back from 1 000 The student can read and produce the number just before a given number in the range 1 to 1 000.
6 BNWS back from 1 000 000 The student can read and produce the number just before a given number in the range 1 to 1 000 000.

Fractional Numbers

(24) **Here are some fractions. Say each fraction as I show it**. Give the student the symbol cards for 1/3, 1/4, 1/5, 1/2, 1/6.

(25) Give the student the unit fraction cards from question (24). **Put these fractions in order from smallest over here**, indicating left, **to largest over here**, indicating right. If correct ask, **Why do you think one-quarter is less than one-third?** Does the student explain the effect of increasing the bottom number (denominator) as decreasing the value of the fraction?

(26) Show the student the test booklet page with 6/8, 1 2/6, 1 1/3, 1 2/14, on it. Point to the fraction 6/8. **Which of these numbers are the same as 8/6?** If correct, check that the answer is not a guess by asking **Explain how you know this**.

If the student orders unit fractions but cannot recognise that 8/6 is equivalent to 1 2/6 or 1 1/3, rate him/her at stage 5.

Rate the student at the highest stage in which he/she gets all relevant questions (24) to (26) correct.

Stage & Behavioural Indicator

2–3 Unit Fractions Not Recognised The student cannot identify symbols for unit fractions.
4 Unit Fractions Recognised The student can read unit fraction symbols, for example, the student can read 1/3 as one-third, ¼ as one-quarter.
5 Ordered Unit Fractions The student can compare unit fractions, for example, 1/3 > 1/4
6 Co-ordinated Numerators and Denominators The student describes the size of fractions with reference to both the numerator and denominator, for example, 8/6 is one whole and two-sixths or one whole and one-third.

Place Value

For the following questions, students should be rated by their fluent recall. Prolonged use of strategising suggests the student does not know the answer.

For each question (27) to (33), show the equation and read it aloud, or use the cards provided [Question (33)].

The student must correctly answer all of questions ...

(27), without counting, to be rated at stage 4, otherwise rate them at stage 3
(28) and (29) to be rated at stage 5
(30) and (31) to be rated at stage 6
(32) and (33) to be rated at stage 7.

Where the student shows knowledge gaps, rate him/her at the previous stage, and move to the Basic Facts section.

Tell me the answer to ...
(27) **A toy costs $80. How many $10 notes do you need to pay for it?**

(28) **A radio costs $230. How many $10 notes do you need to pay for it?**

(29) **What number is the arrow pointing to? How do you know?**
Both 6.8 and 6 and 8 tenths are acceptable answers.

(30) **You have $26,700 in $100 notes. How many notes do you have?**

(31) **What number is three tenths more than 4.8? How do you know?**

(32) **How many tenths are in all of this number? 4.67** Circle 4.67 with index finger. While 46 tenths is the expected answer, 46.7 tenths is also acceptable.

(33) **Put these decimals** (0.39, 0.478, 0.8) **in order from smallest over here**, indicating left, **to largest over here**, indicating right.

Stage & Behavioural Indicator

4 Ten as a Counting Unit The student uses ten as a counting unit, for example, 10, 20, 30, 40, 50, 60, to find the number of tens in 60.
5 Tens in numbers to 1 000, Tenth as a Counting Unit The student knows how many tens are in whole numbers to 1 000 and recognizes tenths among whole numbers.
6 Hundreds in Whole Numbers, Connected Tenths and Ones The student knows how many hundreds are in any whole number to 100 000 and recognises that ten tenths make one.
7 Tenths in Decimals/Ordered Decimals The student knows how many tenths are in numbers with two decimal places, for example, 7.56 has 75 or 75.6 tenths, and orders decimals to three places, for example, 0.539, 0.6, 0.72.

Basic Facts

For the following questions, students should be rated by their fluent recall. Prolonged use of strategising suggests the student does not know the answer, and must work it out. For each question (34) to (48), show the equation in the test booklet and read it aloud. Cease the interview at the line of questions at which the student has knowledge gaps and rate them using the indicators below.

What is the answer to ...

(34) **2 + 3**	(35) **5 + 4**	(36) **6 and what makes 10?**	
(37) **6 + 6**	(38) **9 + 9**	(39) **10 + 4**	(40) **7 + 10**
(41) **8 + 6**	(42) **6 + 9**	(43) **8 x 5**	(44) **5 x 7**
(45) **17 – 9**	(46) **15 – 6**	(47) **6 x 7**	(48) **8 x 4**

Stage & Behavioural Indicator

2 Addition Facts to Five The student instantly recalls facts to five, for example, 2 + 3.
3 Addition Facts to Ten The student instantly recalls facts to ten, for example, 5 + 4, 6 + □ = 10.
4 Addition Facts with Tens and Doubles The student recalls the doubles to 20, and teen facts, for example, 14 = 10 + 4.
5 Addition Facts The student recalls the basic addition facts, and the multiplication facts for 2, 5, and 10.
6 Subtraction and Multiplication Facts The student recalls the basic subtraction and multiplication facts.

Numeracy Project Assessment Form C

Transfer the notes from the Strategy Windows tasks (pages 4 and 5) to the addition and subtraction stage boxes on the Individual Assessment Sheet.

Operational Strategy Questions
Multiplication and Division

Things the interviewer says are in bold. Comments for the interviewer appear in plain type.

(1) **Here is a forest of trees. There are 5 trees in each row, and there are 8 rows.** Use horizontal and vertical sweeps with index finger. Mask all but one horizontal and one vertical edge of the array. **How many trees are there in the forest altogether?** If the student is unable to give an answer, uncover the rest of the sheet.
If I planted 15 more trees, how many rows of 5 would I have then altogether?

For questions (2) and (3), screen the answer then uncover it if the student responds correctly. If the student gives no response or an incorrect response, rate him/her at no higher than stage 5 on multiplication and division and proceed to the proportions and ratios section.

(2) **What is 3 x 20? If 3 x 20 = 60, what does 3 x 18 equal?**
Does the student derive 3 x 18 by 60 – 6 = 54?

(3) **What is 5 x 8? If 5 x 8 = 40, what does 5 x 16 equal?**
Does the student derive 5 x 16 = 80 by doubling 40?
If the student does not derive the answers to questions (2) and (3), rate him/her at either stage 4 or 5 and proceed to the questions on proportions and ratios.

(4) **There are 24 muffins in each basket. How many muffins are there altogether?**
Does the student use a part-whole strategy such as place value partitioning, for example, 6 x 20 = 120, 6 x 4 = 24, 120 + 24 = 144; tidy numbers, for example, 6 x 25 = 150, 150 – 6 = 144; or proportional reasoning, for example, 6 x 24 = 12 x 12 = 144 (doubling and halving)?

(5) **At the car factory, they need 4 wheels to make each car. How many cars could they make with 72 wheels?**
Does the student use a part-whole strategy such as standard place value partitioning, for example, 40 ÷ 4 = 10, 72 – 40 = 32, 32 ÷ 4 = 8, 10 + 8 = 18; tidy numbers, for example, 80 ÷ 4 = 20 so 72 ÷ 4 = 20 – (8 ÷ 4) = 18; reversing, for example, 10 x 4 = 40, 8 x 4 = 32 so 18 x 4 = 72 (multiplying to solve a division problem); proportional reasoning and reversing, for example, 9 x 8 = 72 so 18 x 4 = 72 (doubling and halving) so 72 ÷ 4 = 18 (reversing)?
If the student solves any of questions (4) or (5) successfully using at least two different advanced strategies, rate him/her at stage 7 for multiplication and division and proceed to questions (6) and (7). Otherwise rate the student at stage 6.

(6) **Ivan has 2.4 kilograms of mince. Each patty takes 0.15 kilograms of mince. How many patties can Ivan make?**
Does the student use a mental part-whole strategy such as doubling, 2 x 0.15 = 0.3 so 4 x 0.15 = 0.6 so 16 x 0.15 = 2.4; reversing with rounding and place value, 10 x 0.15 = 1.5 so 20 x 0.15 = 3.0 so 16 x 0.15 = 2.4?

(7) **Each day on the life raft, 22 litres of water are shared equally among the 8 survivors. How much water, in litres, does each person get each day?**
Does the student use mental part-whole strategies such as: standard place value, 16 ÷ 8 = 2, 6 ÷ 8 = 0.75, so 22 ÷ 8 = 2.75; converting equivalent fractions to decimals, 22 ÷ 8 = 2 6/8 = 2 ¾ = 2.75?
If the student solves both questions (6) and (7) using two different advanced strategies, rate him/her at stage 8 for multiplication and division. Otherwise rate the student at stage 7.
Where the student images a written algorithm, no assumption can be made about their stage. Question the student about their understanding of the processes involved in the algorithm and what other strategies they could use to solve the given problem.

Stage & Behavioural Indicator

4 Advanced Counting The student solves multiplication problems by skip-counting where he/she has a known sequence or by using a combination of skip-counting and counting in ones, for example, 5, 10, 15, 20.
5 Early Additive Part-Whole The student solves multiplication problems by forming the factors where they have a known multiplication fact or using repeated addition, for example, for 6 x 4: 4 + 4 = 8, 8 + 4 = 12, 12 + 12 = 24.
6 Advanced Additive–Early Multiplicative Part-Whole The student solves multiplication problems by deriving from known multiplication facts, for example, 3 x 20 = 60 so 3 x 18 = 60 – (3 x 2) = 54.
7 Advanced Multiplicative–Early Proportional Part-Whole The student is able to use at least two different advanced mental strategies to solve multiplication and division problems with whole numbers.
8 Advanced Proportional Part-Whole The student is able to use at least two different advanced mental strategies to solve multiplication and division problems with decimals and fractions with related denominators.

(8) Show the student the fraction circle sheet in the test booklet (page 43). **Which of these cakes has been cut into thirds?** If the student responds incorrectly, identify (point to) the thirds. **Here are 12 jelly beans to spread out evenly on top of the cake. You eat one third of the cake. How many jelly beans do you get?** If the student cannot answer the question, allow them to manipulate the beans or counters to find it.

For students who need to equally share the beans/counters, either with materials or by imaging the movement of the materials, rate them at stages 2–4 for proportions and ratios and proceed to the knowledge questions (page 36).

(9) **What is ¾ of 28?** Does the student use a part-whole strategy based on addition and/or multiplication? If the student uses part-whole strategies based on addition and/or halving, continue on to question (10) as this item may lead them to using division.

(10) **12 is 2/3 of a number. What is the number?**
For students who are unsuccessful at question (10), rate them at either stage 5 or 6, whatever is appropriate from their response to question (9), and proceed to the knowledge questions. Answering question (10) using multiplication and division places the students at stage 7 at least. If the student uses part-whole strategies successfully for both questions (11) and (12), rate them at stage 8.

(11) **It takes 10 balls of wool to make 15 beanies. How many balls of wool does it take to make 6 beanies?** Show the question in the test booklet (page 44). Does the student use a part-whole strategy based on equivalent fractions such as finding relationships between different units, for example, 10 → 15 so 1→ 1.5 so 4 → 6 (unit fractions), or 6 x 2 ½ = 15 so □ x 2 ½ = 10; or finding relationships within the same units, for example, 10 → 15 so 20→ 30 so 4 → 6?

(12) **There are 21 boys and 14 girls in Ana's class. What percentage of Ana's class are boys?** Show the question in the test booklet (page 44). Does the student use a part-whole strategy based on equivalent fractions such as finding relationships between different units, for example, 21 ÷ 7 = 3, 14 ÷ 7 = 2 (common factor); 21 → 35 so 3 → 5 so 60 → 100, so 3/5 = 60% are boys; or finding relationships within the same units, for example, 35 x 3 = 105 so 21 x 3 = 63 and adjust down to 60%.

Stage & Behavioural Indicator

2–4 Equal Sharing The student finds a fraction of a number by sharing the objects into equal subsets physically or by imaging.
5 Early Additive Part-Whole The student finds a unit fraction of a number mentally using trial and improvement with addition facts, for example, 1/3 of 12 as 4 + 4 + 4 = 12.
6 Advanced Additive–Early Multiplicative Part-Whole The student finds a fraction of a number mentally using a combination of addition facts and multiplication, for example, ¾ of 28 as: ¼ of 20 = 5 so ¼ of 24 = 6 so ¼ of 28 = 7, 3 x 7 = 21; or ½ of 28 is 14, ½ of 14 is 7, 14 + 7 = 21.
7 Advanced Multiplicative–Early Proportional Part-Whole The student finds a fraction of a number using division and multiplication, for example, 2/3 x □ = 12 so 1/3 x □ = 6 so □ = 6 x 3 = 18, or 1½ x 12 = □ so □ = 18.
8 Advanced Proportional Part-Whole The student uses at least two different strategies to solve problems that involve equivalence with and between fractions, ratios, and proportions, for example, 75% of 36 as ¾ of 36; or 12 → 8 as □ → 18: 12 → 8 so 3 → 2 (dividing by four) so 27 → 18 (multiplying by nine).

Knowledge Questions
Forwards and Backwards Number Word Sequence

Show the number sequence cards. Stop at the point the student encounters difficulty and proceed to the fractions questions.

For each number I show you, tell me the number that comes just after it, the number that is one more. Also tell me the number that comes just before it, the number that is one less.

(13) **2 400** (14) **3 049** (15) **603 000** (16) **989 999**

Stage & Behavioural Indicator

5 FNWS and BNWS within 1 000 The student can produce the number before and after a given number in the range 1 to 1 000.
6 FNWS and BNWS within 1 000 000 The student can produce the number before and after a given number in the range 1 to 1 000 000.

(17) **Here are some fractions. Say each fraction as I show it**. Show the student the symbol cards for 1/3, 1/4, 1/5, 1/2, 1/6 one at a time. Lay the cards on the table as they are shown.
If the student is unable to recognise the fractions, rate him/her at stage 2–3.

(18) Referring to the fraction cards from question (17) … **Put these fractions in order from smallest over here**, indicating left, **to largest over here**, indicating right. If correct, ask, **Why do you think one-quarter is less than one-third?** Does the student explain the effect of increasing the bottom number (denominator) as decreasing the value of the fraction?
If the student can recognise the unit fractions but cannot order them, rate him/her at stage 4.

(19) Show the student the test booklet page (page 45) with 6/8, 1 2/6, 1 1/3, 1, and 2/14 on it. Point to the fraction 8/6. **Which of these numbers are the same as 8/6?** If the student is correct, check that the answer is not a guess by asking **Explain how you know this.**
If the student orders unit fractions but cannot recognise that 8/6 is equivalent to 1 2/6 or 1 1/3, rate him/her at stage 5.

(20) Give the student the set of mixed fractions, 2/5, 7/16, 1/2, 2/3, 6/9, 3/4. **Here are some fractions. Put them in order from smallest over here**, indicating left, **to largest over here**, indicating right. Does the student recognise the equivalence of two-thirds and six-ninths? If so, rate them at stage 7 at least, if not rate them at stage 6. Rate a student who successfully orders all the fractions in question (20) at stage 8.

Stage & Behavioural Indicator
2-3 Unit Fractions Not Recognised The student cannot identify symbols for unit fractions.
4 Unit Fractions Recognised The student can read unit fraction symbols, for example, the student can read 1/3 as one-third, ¼ as one-quarter.
5 Ordered Unit Fractions The student can compare unit fractions, for example, 1/3 > 1/4.
6 Co-ordinated Numerators and Denominators The student describes the size of fractions with reference to both the numerator and denominator, for example, 8/6 is one whole and two-sixths.
7 Equivalent Fractions The student names equivalent fractions from a set of fractions with different denominators, for example, 2/3 = 8/12, 3/4 = 6/8.
8 Ordered Fractions The student orders fractions with unlike denominators and numerators, for example, 2/5 < 7/16.

Place Value

For the following questions, students should be rated by their fluent recall. Prolonged use of strategising suggests the student does not know the answer, and must work it out.
The student must correctly answer all of questions...
(21) and (22) to be rated at stage 5, otherwise rate them at stage 4.
(23) and (24) to be rated at stage 6,
(25) and (26) to be rated at stage 7,
(27) to (30) to be rated at stage 8.
Where the student shows knowledge gaps, rate him/her at the previous stage.

(21) **A radio costs $230. How many $10 notes do you need to pay for it?**

(22) **What number is the arrow pointing to? How do you know?**
Both 6.8 and 6 and 8 tenths are acceptable answers.

(23) **You have $26,700 in $100 notes. How many notes do you have?**

(24) **What number is three tenths less than 2? How do you know?**

(25) **How many tenths are in all of this number? 4.67** Circle 4.67 with index finger. While 46 tenths is the expected answer, 46.7 tenths is also acceptable.

(26) **Put these decimals** (0.39, 0.478, 0.8) **in order from smallest over here**, indicating left, **to largest over here**, indicating right.

(27) **How many hundredths are in all of this number? 2.097** Circle 2.097 with index finger. While 209 hundredths is the expected answer, 209.7 hundredths is acceptable.

(28) **Round 7.649 to the nearest tenth.**

(29) **Give three numbers that are between 7.59 and 7.6. If you had time, how many numbers could you find?**

(30) **Name 137.5% as a decimal.**

Stage & Behavioural Indicator
5 Tens in numbers to 1 000, Tenth as a Counting Unit The student knows how many tens are in numbers to 1 000, and recognises tenths among whole numbers.
6 Hundreds in Whole Numbers, Connected Tenths and Ones The student knows how many hundreds are in any whole number to 100 000, and recognises that ten tenths make one.
7 Tenths in Decimals/Ordered Decimals The student knows how many tenths are in numbers with two decimal places, for example, 7.56 has 75 or 75.6 tenths, and orders decimals to three places, for example, 0.539, 0.6, 0.72.
8 Decimal Conversions The student knows how many hundredths are in decimals, and rounds numbers to the nearest tenth, for example, 7.649 → 7.6 to the nearest tenth, not 7.7. The student can identify decimals between others and name a percentage as a decimal and vice versa, for example, 137.5% as 1.375.

Basic Facts

For the following questions, students should be rated by their fluent recall. Prolonged use of strategising suggests the student does not know the answer, and must work it out. For each question (31) to (43), show the equation in the test booklet (page 48) and read it aloud. Cease the interview at the line of questions at which the student has knowledge gaps and rate them using the indicators below.

What is the answer to ...

(31) **8 + 6**	(32) **6 + 9**	(33) **8 x 5**	(34) **5 x 7**
(35) **17 – 9**	(36) **15 – 6**	(37) **6 x 7**	(38) **8 x 4**
(39) **56 ÷ 7**	(40) **63 ÷ 9**		

For questions (41) to (43) explain the meaning of the terms, factor, common factor, and least common multiple, if necessary.

(41) **Name all the factors of 81.**

(42) **What is the highest common factor of 72 and 81?**

(43) **What is the least common multiple of 8 and 12?**

Stage & Behavioural Indicator

4 Addition Facts with Tens and Doubles The student recalls the doubles to 20, and “teen” facts, for example, 14 = 10 + 4.
5 Addition Facts The student recalls the basic addition facts, and the multiplication facts for 2, 5, and 10.
6 Subtraction and Multiplication Facts The student recalls the basic subtraction and multiplication facts.
7 Division Facts The student recalls the basic division facts and names all the factors of numbers to 100.
8 Common Factors and Multiples The student names all the common factors of two numbers to 100, and the least common multiple of numbers to 10.